THE JOURNAL
OF THE
ROYAL AERONAUTICAL SOCIETY

(FOUNDED 1897 in succession to the ANNUAL REPORTS)

Edited for the Council by J. LAURENCE PRITCHARD, Fellow

No. 195. MARCH, 1927. Vol. XXXI.

NOTICES

Elections

The following Members were elected at a Council Meeting held on February 8th, 1927:—

Fellows.—Major J. S. Buchanan, O.B.E., A.M.I.E.E., Mr. C. C. Walker.

Associate Fellows.—Wing Commander C. D. Breese, A.F.C., Mr. C. G. Chatfield, M.S.A.E., Mr. J. Lankester Parker.

Associates.—Mr. C. B. Harris, Mr. H. Sykes, O.B.E.

Students.—Mr. S. D. Davies, Mr. J. W. Maccoll.

Members.—Mr. T. Crabtree, Mr. D. Bower, Mr. H. Spooner, Mr. T. R. Thomas, B.Sc., Air Vice-Marshal Sir Vyell Vyvyan, K.C.B., D.S.O.

Annual General Meeting

The Annual General Meeting will be held in the Library on Tuesday, March 29th, at 5.0 p.m. The Statement of Accounts for the year ending December 31st, 1926, and the Council's Annual Report will be found on page 175. of this issue.

Notice of any subject to be brought up for discussion at the meeting must be received by the Secretary not later than March 15th. Nominations for election to the vacancies on the Council, signed by two voters and accompanied by a statement signed by the candidate signifying his willingness to serve if elected, must be received by the Secretary not later than March 10th.

Particular attention is drawn to the proposed alterations to the Rules, as set out in the Annual Report of the Council, and to the terms of amalgamation with the Institution of Aeronautical Engineers.

Library Fund

The Council gratefully acknowledge the donation by Sir Mackenzie Chalmers of twenty guineas to the Library Fund.

£10,000 *Endowment Fund*

The Council gratefully acknowledge the gift of two guineas to the £10,000 Endowment Fund from Mr. W. Villa Gilbert. The Fund now stands as follows:

"A Friend of Aviation"	£100	0	0
Sir Charles C. Wakefield	250	0	0
Mr. H. Scott Paine	50	0	0
Anglo-American Oil Company	50	0	0
Shell Mex	50	0	0
British Petroleum	50	0	0
Sir Mackenzie Chalmers	25	0	0
Mr. W. Villa Gilbert	2	2	0
	£577	2	0

The Council would be very glad to receive more donations to this Fund, all of which will be acknowledged in the Journal.

In connection with the Fund, the particular attention of all members of the Society is drawn to the letter from the Duke of York published in the Annual Report.

Informal Discussions

As an experiment, an informal discussion and dinner of the Society was held on February 7th in rooms kindly put at the Society's disposal by the Royal Aero Club. The experiment was so successful that it is felt by the Council that it should be repeated as often as possible. A report of this discussion and other informal discussions given recently before the Society will appear in the April Journal.

The Hampshire Air Pageant

An Air Pageant is being organised by the Hampshire Aeroplane Club to take place on Sunday, May 15th, at Southampton Aerodrome, Hamble. It will be the first pageant in the world to display Landplanes, Seaplanes and Flying Boats. The pageant is organised in sections, and delay will be obviated if correspondence is addressed to the appropriate section, Hampshire Air Pageant, Hamble, Southampton. The sections are as follows:—Enclosures, Traffic and Police, Publicity, Tickets, Entries, Bands and Wireless, Refreshments, Transport, Programmes, Finance, Engineering.

Special Lectures

In addition to the programme arranged for the present Session, two special lectures will take place which should prove particularly interesting. Group Captain Flack, C.B.E., M.B., M.A., will read a paper entitled, "Man and the Machine," on Thursday, March 10th, at 6.30 p.m., at the Royal Society of Arts, 18, John Street, Adelphi, W.C.2. Slides will be shown. An apparatus for testing the suitability of candidates for flying will be on view, and it is hoped to show the apparatus actually in use.

Major Wronsky's paper on German Commercial Air Development will be read, in English, at 6.30 p.m., on Thursday, March 24th, at the Royal Society of Arts. The lecture will be illustrated by slides and a film.

Flight Lieutenant F. O. Soden, D.F.C., will give a lecture on "Parachutes" on the 7th April, at 5.15 p.m., at the Royal Society of Arts. During the course of his lecture he will exhibit slow motion and other films.

The attention of all members, who wish to attend, is particularly called to the change of time from 6.30 p.m. to 5.15 p.m.

Forthcoming Events

Thursday, March 3rd.—At 6.30 p.m., at the Royal Society of Arts, Mr. L. W. Bryant, B.Sc., A.R.C.Sc., A.F.R.Ae.S., and Mr. S. B. Gates, M.A., "The Spinning of Aeroplanes."

Thursday, March 10th.—At 6.30 p.m., at the Royal Society of Arts, Group Captain M. Flack, C.B.E., M.B., M.A., "Man and the Machine."

Thursday, March 17th.—At 6.30 p.m., at the Royal Society of Arts, Mr. M. A. Giblett, M.Sc., "Line Squalls."

Thursday, March 24th.—At 6.30 p.m., at the Royal Society of Arts, Major M. Wronsky, "German Commercial Air Development."

Tuesday, March 29th.—At 5.0 p.m., in the Library, Annual General Meeting.

Thursday, March 31st.—At 6.30 p.m., at the Royal Society of Arts, Mr. E. G. Richardson, M.Sc., Ph.D., "Recent Model Experiments in Aerodynamics."

J. LAURENCE PRITCHARD, *Secretary.*

CORRESPONDENCE

To the Editor of the JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY.

SIR,—In my paper entitled "The Langley Machine and the Hammondsport Trials," published in the AERONAUTICAL JOURNAL of December, 1921, I stated that the machine, after the Hammondsport trials, was returned to the Smithsonian Institution at Washington, D.C., and the original portions still remaining were utilised in the reconstruction of a facsimile of the original Langley machine. This reconstructed machine is now exhibited in the U.S. National Museum with the following inscription:—

ORIGINAL LANGLEY FLYING MACHINE, 1903.

THE FIRST MAN-CARRYING AEROPLANE IN THE HISTORY OF THE WORLD CAPABLE OF SUSTAINED FREE FLIGHT. INVENTED, BUILT AND TESTED OVER THE POTOMAC RIVER BY SAMUEL PIERPONT LANGLEY IN 1903. SUCCESSFULLY FLOWN AT HAMMONDSPORT, N.Y., JUNE 2, 1914.

Since 1921 I have visited the U.S. National Museum every year in order to observe any correction or change in this incorrect inscription, and last month (January, 1927) I again visited the Museum and observed that the label had been changed to the following:—

LANGLEY AERODROME.

THE ORIGINAL LANGLEY FLYING MACHINE OF 1903,

RESTORED.

IN THE OPINION OF MANY COMPETENT TO JUDGE, THIS WAS THE FIRST HEAVIER-THAN-AIR CRAFT IN THE HISTORY OF THE WORLD CAPABLE OF SUSTAINED FREE FLIGHT UNDER ITS OWN POWER, CARRYING A MAN.

THIS AIRCRAFT SLIGHTLY ANTEDATED THE MACHINE DESIGNED AND BUILT BY WILBUR AND ORVILLE WRIGHT WHICH, ON DECEMBER 17, 1903, WAS THE FIRST IN THE HISTORY OF THE WORLD TO ACCOMPLISH SUSTAINED FREE FLIGHT UNDER ITS OWN POWER, CARRYING A MAN.

This new inscription is a step towards the truth, for it changes a statement of fact into one of opinion. In view of the fact, however, that the opinion arrived at is clearly incorrect, it is evident that those forming it were not competent to judge.

In smaller print, the label then continues as follows:—

> "The aeronautical work of Samuel Pierpont Langley, third Secretary of the Smithsonian Institution, was begun in 1887. By fundamental scientific research he discovered facts, the publication of which largely laid the foundation for modern aviation. Langley designed large model aeroplanes which repeatedly flew in 1896 with automatic stability for long distances. The U.S. War Department, impressed by his success,

> authorised him to construct a man-carrying machine which was completed in the Smithsonian shops in the spring of 1903. Attempts made to launch it on October 7 and December 8, 1903, failed owing to imperfect operation of the catapult launching device. In these trials the wings and control surfaces were badly damaged and lack of funds prevented other tests at this time. The aeroplane was left by the War Department with the Smithsonian Institution for further experiments. In 1914 (following the foundation by the Smithsonian Institution of the Langley Aerodynamical Laboratory) the experiments were resumed, using all available parts of the original machine. The frame and engine were the same as in the first trials; the reconstructed wings were used without the leading edge extension; the control surfaces were reconstructed; and launching pontoons with necessary trussing were substituted for the original catapult. Thus equipped, and weighing over 40 per cent. more than in 1903, with Glenn H. Curtis as the pilot, it was successfully flown at Hammondsport, N.Y., June 2, 1914. With a more powerful engine and tractor propeller it was subsequently flown repeatedly. These tests indicated that the original machine would have flown in 1903 had it been successfully launched. After the Hammondsport flights the machine was restored in accordance with the original drawings and data under the supervision of one of the original mechanics, using all original parts available. In 1918 the machine thus restored was deposited in the National Museum for permanent exhibition. Its 52 horse-power gasoline engine was designed by Charles M. Manley, who superintended the construction of the machine and piloted it in 1903."

The above added paragraph is misleading and incorrect in many particulars, which will be evident to anyone reading my original paper in the AERONAUTICAL JOURNAL.

I hope to continue my visits to the U.S. National Museum and to report at some future date a further change in the inscription, when it will be acknowledged that the machine which was tested at Hammondsport was not the original Langley machine, but was merely a part of the frame, with the newly-built remainder of the machine altered in design in many respects to conform with later aeronautical knowledge. The new inscription will also acknowledge that a system of lateral control, unknown to Langley, was introduced into the Hammondsport machine.

I am, Sir, your obedient Servant,

GRIFFITH BREWER.

ROYAL AERONAUTICAL SOCIETY

SIXTY-SECOND ANNUAL REPORT OF THE COUNCIL, 1926-1927

Council

Chairman: Colonel the Master of Sempill, A.F.C., A.F.R.Ae.S.
Vice-Chairman: Air Vice-Marshal Sir W. Sefton Brancker, K.C.B., A.F.C., F.R.Ae.S.
Captain P. D. Acland.
Mr. Griffith Brewer, F.R.Ae.S.
Wing Commander T. R. Cave-Browne-Cave, C.B.E., F.R.Ae.S.
Sir Mackenzie D. Chalmers, K.C.B., C.S.I.
Mr. C. R. Fairey, C.B.E., F.R.Ae.S.
Captain G. T. R. Hill, M.C., M.Sc., F.R.Ae.S.
Mr. H. B. Irving, A.F.R.Ae.S.
Major A. R. Low, F.R.Ae.S.
Mr. W. O. Manning, F.R.Ae.S.
Major R. H. Mayo, O.B.E., F.R.Ae.S.
Lieut.-Colonel M. O'Gorman, C.B., D.Sc., F.R.Ae.S.
Mr. F. Handley Page, C.B.E., F.R.Ae.S.
Major G. H. Scott, C.B.E., A.F.C., F.R.Ae.S.
Mr. T. O. M. Sopwith, C.B.E., F.R.Ae.S.
Mr. C. W. Tinson, F.R.Ae.S.
Mr. H. T. Vane.
Sir Henry White-Smith, C.B.E.
Mr. H. E. Wimperis, O.B.E., F.R.Ae.S.
Mr. R. McKinnon Wood, F.R.Ae.S.
Honorary Treasurer: Mr. A. E. Turner.
Honorary Librarian: Mr. J. E. Hodgson.
Honorary Solicitor: Mr. B. Woodward.
Secretary: Mr. J. Laurence Pritchard, Hon.F.R.Ae.S.
Assistant Secretary: Miss O. St. B. St. Barbe.
Honorary Secretary Students' Branch: Mr. Scott Hall, B.Sc.
Honorary Secretary Coventry Branch: Mr. F. Meadows, A.F.R.Ae.S.
Honorary Secretary Yeovil Branch: Mr. V. S. Gaunt, A.R.Ae.S.

Membership

The following table of the membership position on 1st January, 1927, has been prepared, showing the state of each grade. The figures in brackets show the corresponding membership on 1st January, 1926:—

Grade.	No. of Members.	Hon. and Life Members.	Suspended.	Totals.
Fellows	79 (50)	14 (13)	1 (—)	94 (72)
Associate Fellows	283 (284)	8 (8)	5 (6)	296 (298)
Associates (New Grade) ...	51	2 (—)	—	53
Students	63 (62)	—	— (8)	63 (70)
Members	131 (136)	16 (17)	5 (26)	152 (159)
Founder Members	49 (50)	—	— (1)	49 (51)
Coventry Branch (New Branch)	229	—	—	229
Yeovil Branch (New Branch)...	113	—	—	113
	999 (591)	40 (38)	11 (21)	1049 (650)

Alterations in the Rules

The Council will propose at the Annual General Meeting that Rule 19, paragraph (*a*), which now reads:—

> "At a meeting held in June in each year the Council shall appoint a Chairman, who shall take office in the following October and hold office for one year. He shall be an *ex-officio* member of the Council and of all Committees appointed by the Council, and shall preside at all Meetings at which he shall be present in the absence of the President. He shall not be eligible for re-election on the expiry of his year of office,"

shall be amended to read as follows:—

> "At a meeting held in June in each year, the Council shall appoint a Chairman, who shall take office in the following October and hold office for one year. He shall be an *ex-officio* member of the Council and of all Committees appointed by the Council, and shall preside at all meetings at which he shall be present, in the absence of the President. He shall be eligible for re-election on the expiry of his year of office for one further year, but, if elected for a second year, he shall not be eligible again for further election until two years have elapsed, when he shall be eligible."

And Rule 19, paragraph (*c*), which now reads:—

> "The Vice-Chairman of the Society shall be the retiring Chairman. He shall be an *ex-officio* member of the Council and of all Committees year. He shall preside at all meetings at which he shall be present in the absence of the President and Chairman,"

shall be amended to read as follows:—

> "The Vice-Chairman of the Society shall be the retiring Chairman. He shall be an *ex-officio* member of the Council and shall hold office for one appointed by the Council and shall hold office for one year. He shall preside at all meetings at which he shall be present in the absence of the President and Chairman. In the case of a Chairman being elected for two years in succession the Council may ask the existing Vice-Chairman to continue his office for a second year, or may elect a member of the Council to this office for the same period."

And Rule 18, which now reads:—

> "The President must be a Voter and shall be appointed by the Council. He shall be an *ex-officio* member of the Council and of all Committees appointed by the Council, and shall be entitled to preside at all meetings at which he shall be present,"

shall be amended to read as follows:—

> "The President must be a Voter and shall be appointed by the Council. He shall take office for one year, but shall be eligible for re-election for a further period of one year after his first year of office. If elected for a second year he shall not be eligible again for further election until two years have elapsed, when he shall be eligible. He shall be an *ex-officio* member of the Council and of all Committees appointed by the Council, and shall be entitled to preside at all meetings at which he shall be present."

Amalgamation with the Institution of Aeronautical Engineers

Many members of the Royal Aeronautical Society and of the Institution of Aeronautical Engineers felt that, when negotiations for amalgamation failed in 1925, no insuperable conditions had been suggested by either body.

Further negotiations have taken place during the year to bring about a friendly amalgamation between the Royal Aeronautical Society and the Institution of Aeronautical Engineers. The Council have long felt that it would be in the interests of all concerned to bring about such an amalgamation in order that full advantage can be taken, in the interests of aeronautics, of the energy

and funds now being used separately. Meetings between representatives of the two bodies have been held under the chairmanship of Sir George Beharrell, many points of disagreement have been cleared up, and a general agreement on the desirability of amalgamation has been reached. These proposals have been carefully considered by the Council, who are of the opinion that they offer a sound basis for agreement between the two bodies. The proposals of the Beharrell Committee will be placed before the Annual General Meeting for ratification.

The following is the report of that Committee:—

Minutes of a Joint Committee Meeting of the Royal Aeronautical Society and the Institution of Aeronautical Engineers, under the Chairmanship of Sir George Beharrell, held in the Board Room of the Dunlop Company, at 5.30 p.m., on January 27th, 1927.

PRESENT.—In the Chair, Sir George Beharrell.

Representatives of the Royal Aeronautical Society.

Colonel the Master of Sempill (Chairman of the Society).
Captain P. D. Acland.
Wing Cmdr. T. R. Cave-Browne-Cave.
Major R. H. Mayo.
Mr. F. Handley Page.
Mr. J. Laurence Pritchard (Secretary).

Representatives of the Institution of Aeronautical Engineers.

Mr. M. L. Bramson.
Mr. L. Howard Flanders.
Mr. F. R. Simms.
Captain A. P. Thurston.
Mr. L. A. Wingfield.
Mr. N. J. Hulbert (Honorary Secretary).

Colonel Sempill, on behalf of the Royal Aeronautical Society, and Dr. Thurston, on behalf of the Institution of Aeronautical Engineers, respectively, having thanked Sir George Beharrell for having so kindly renewed his interest in the question and lent the Board Room of the Dunlop Company,

The following resolutions were passed by the Joint Committee:—

I.—That the name and title of the amalgamated Society shall be "The Royal Aeronautical Society" with which is incorporated the Institution of Aeronautical Engineers.

II.—In the Amalgamated Society the title Hons. Member of the Institution of Aeronautical Engineers shall be dropped. Hons. Members and Members of the Institution of Aeronautical Engineers shall have the option of being Fellows of the Royal Aeronautical Society, or continuing to describe themselves as Members of the Institution of Aeronautical Engineers; and Associate Members of the Institution of Aeronautical Engineers shall have the option of being Associate Fellows of the Royal Aeronautical Society, or continuing to describe themselves as Associate Members of the Institution of Aeronautical Engineers. No person becoming a member of the amalgamated Society in pursuance to these resolutions shall be liable to an entrance fee, and no such person shall be liable to an increased subscription during 1927.

III.—That a Committee shall be set up as soon as possible to consider amendments to the Rules and to make recommendations. The Committee shall consist of an agreed Chairman and four members, two being present members of the Institution of Aeronautical Engineers. That this Committee should deal *inter alia* with the rates of subscriptions and future entrance fees, and the grading of any members of the Institution of Aeronautical Engineers not covered by II.

IV.—That the amalgamation, as defined by the provisions herein, shall come into force on July 1st, 1927, and the representatives of each party shall at once seek authority for this purpose. The Council of the Amalgamated Society shall consist of a Chairman and 20 members, of whom thirteen shall be members of the Council of the Royal Aeronautical Society and seven shall be members of

the Council of the Institution of Aeronautical Engineers. Seven members of Council of the Royal Aeronautical Society, as it exists before that date, shall resign for the purpose of co-opting the necessary members of the Institution of Aeronautical Engineers.

V.—That, pending amalgamation, the Honorary Solicitors of the two bodies should act in a joint capacity to advise on all legal questions that may be raised.

(Signed) GEORGE BEHARRELL.

Library

For the third year in succession the Council have to thank Mr. J. E. Hodgson, the Honorary Librarian, for the time he has given to the Library. During the year Mr. Hodgson has revalued the books. Many of these are extremely rare, and the Library of the Society is now one of the most valuable and comprehensive aeronautical libraries in the world. A catalogue is being prepared and it is hoped to publish this in the early summer. At present the books are card indexed, not always a convenient method of reference for members who are not in London. It is felt that a printed catalogue will make the value of the Library more widely known and increase the facilities for borrowing books by post.

£10,000 Endowment Fund

Owing to the generosity of Sir Charles Wakefield, the Anglo-American Oil Company, an anonymous "A Friend of Aviation," Shell-Mex, Ltd., and the British Petroleum Co., Ltd., the Endowment Fund has made a good start and now stands at £582. The Council feel very strongly that every effort must be made to increase this fund substantially, and it is hoped during the coming year that many more subscriptions towards it will be received. All donations will be acknowledged in the Journal and members of the Society are asked to take every opportunity for furthering the fund and so putting the Society upon a permanently sound financial basis and enabling it to carry out to the fullest extent the objects for which it exists.

In connection with the above appeal the following letter was received from the Duke of York, Patron of the Society:—

13, Bruton Street,
Mayfair, W.1,
23rd October, 1926.

Dear Sir Sefton Brancker,

I very much regret that I will be unable to be present at the Royal Aeronautical Society's reception on October 25th.

I am proud to feel that the Prince of Wales and I share between us the honour of being Patrons of the oldest aeronautical body in the world, and it would have given me the greatest satisfaction to have been able to attend the reception.

The work of the Society is growing constantly in magnitude and importance. Its position can be maintained and improved only if all those connected either directly or indirectly with aeronautics give their fullest support. The munificent gift from the Guggenheim Trust Fund of the U.S.A. will in a measure enable the scope of the Society's activities to be widened, and I hope that those public-spirited persons or bodies who have in the past done so much to help forward our other great societies will give assistance so that a substantial Endowment Fund may be established.

Yours sincerely,
ALBERT.

Guggenheim Fund for the Promotion of Aeronautics

The Council in September received a letter from the Daniel Guggenheim Fund for the promotion of Aeronautics, signed by Mr. Harry F. Guggenheim,

the President of the Fund, which said, *inter alia*:—" It affords me great pleasure to advise you that the Daniel Guggenheim Fund for the Promotion of Aeronautics has approved a grant of $5,000 to the Royal Aeronautical Society.

" The grant will be available after January 1st, 1927. It is the hope of the Fund that this grant may stimulate the growth and strength of the Society to such a point that within a short while financial assistance from without will be unnecessary."

The Council wish to repeat what they have already cabled to the United States, their grateful thanks to the Trustees of the Fund for their generous gift, which has already enabled them to inaugurate a number of schemes and to appoint a permanent Secretary.

Branches

In the February issue of the Journal draft rules were published for the formation of local branches of the Royal Aeronautical Society. It was felt by the Council that such branches would extend to members resident in the locality advantages similar to those more readily accessible to members living within easy reach of London.

The first branch to be formed was at Coventry, under the direction of Major F. M. Green, Fellow, and Mr. J. D. Siddeley, Fellow, with Mr. F. Meadows, Associate Fellow, as Honorary Secretary. The branch from the beginning has been exceedingly flourishing, largely owing to the efforts of the Honorary Secretary, and the generous assistance given by Mr. Siddeley and Major Green. The Council wish to place on record their appreciation of the efforts of these gentlemen in establishing the Coventry Branch, the membership of which is now 229.

In December, 1926, the Westland Aircraft Society became the Yeovil Branch of the Royal Aeronautical Society. The Honorary Secretary, Mr. V. S. Gaunt, Associate, is to be congratulated on the membership of the branch and the programme of practical lectures which he has arranged. It is hoped to publish many of these lectures in the Journal. The Chairman of the branch is Mr. R. A. Bruce, Fellow of the Society. The branch now numbers 113 members.

Other branches are in the course of formation and the Council look forward to the time when every important aeronautical centre has its branch, so co-ordinating efforts to one common end, the advancement of aeronautics.

It is particularly emphasised that the Society receives no funds whatever from its branches, and is prepared to help them in every possible way to make them flourishing centres of aeronautical progress.

Scottish Branch

During the year the Scottish Branch was wound up. Such a winding up became necessary under the new Branch Rules. A scheme is now being discussed to form local branches in Scotland, corresponding to those formed and being formed in England.

Students' Section

The Council wish to congratulate the Students upon the flourishing condition of its section. This has largely been due to the efforts of Mr. Scott Hall. His resignation, due to obtaining a post out of London, was received with great regret. An able successor has been found in Mr. C. G. L. Hutchinson and there is no doubt that the Students' Section will become of increasing importance, as everyone concerned on the Committee, as well as the general body of Students themselves, are showing a gratifying keenness. The Council feel very strongly that this keenness and co-operation among the Students is of great importance

for the future welfare of the Society and they express the hope that every Student will make special efforts to attend not only their own lectures but those of the Society.

Awards

The R.38 Memorial Prize for 1926 was awarded to Mr. R. V. Southwell, F.R.S., Fellow of the Society, for his paper "On the Calculation of Stresses in the Hulls of Rigid Airships." The paper was published in the Journal for November, 1926.

The Society's Gold Medal was awarded to Mr. F. W. Lanchester, Honorary Fellow, in recognition of the valuable services he has rendered to the science of aeronautics. The medal was presented to Mr. Lanchester on the occasion of the reading of the Wilbur Wright Memorial Lecture on May 27th, 1926.

The Silver Medal of the Society, given annually for the best paper published during the year in the Journal, was awarded to Professor B. Melvill Jones, A.F.C., Fellow, for his paper on "The Control of Stalled Aeroplanes." The paper was published in the Journal for June, 1926.

The Aboim Prize, for the best paper by a Student published in the Journal in 1926, was awarded to Flying Officer R. L. Ragg, for his paper on "Experimental Flying from the Pilot's Point of View." The paper was published in the Journal for November, 1926, and was also awarded the Pilcher Prize for the best paper by a Student inaugurating a discussion.

Elliott Memorial Prize

The Council have decided to give an annual prize of five guineas for a paper by apprentices for the Royal Air Force being trained at Halton, as a memorial to the late Mr. A. B. Elliott, who contributed so greatly to the success of Sir Alan Cobham's flights to India, South Africa and Australia, and who received his early training in the Royal Air Force. The subject of the paper will be decided in collaboration with the Commanding Officer at Halton.

Wilbur Wright Memorial Lecture

The Wilbur Wright Memorial Lecture for 1926 was delivered by Mr. F. W. Lanchester on May 27th, on "Sustentation in Flight." The meeting was made the occasion for holding the Council Dinner to Mr. Lanchester and presenting him with the Gold Medal of the Society.

The Wilbur Wright Memorial Lecture for 1927 will be delivered by Professor Prandtl, perhaps the most outstanding figure of the present time in the advancement of the theory of aeronautics.

Conversazione

On January 12th, 1926, the 60th anniversary of the foundation of the Society was commemorated by a conversazione held at the Science Museum, South Kensington. The conversazione was a brilliant success and was attended by H.R.H. Prince Chichibu of Japan, the Air Minister (Sir Samuel Hoare) and several hundred guests who were received by the President, Air Vice-Marshal Sir Sefton Brancker. A report of the conversazione appeared in the Journal for February, 1926.

Reception to Sir Alan Cobham

There was a large and distinguished gathering at a reception held in the King Edward VII. Rooms, at the Hotel Victoria, Northumberland Avenue, London, W.C.2, on Monday, October 25th, under the auspices of the Society, to meet Sir Alan and Lady Cobham, on the completion of the former's pioneer flight to Australia and back. The reception was preceded by a Council Dinner

to Sir Alan and Lady Cobham, and followed by a lecture by the distinguished pilot. Before the lecture was delivered it was announced that Sir Alan Cobham had been made an Honorary Fellow of the Society, and Sergeant Ward and Mr. Capel, who accompanied him, Life Associates. A report of the reception and the lecture appeared in the Journal for January, 1927.

Associateship

At a Special General Meeting held on December 30th, 1925, it was decided to form a new technical grade, called Associates. Persons belonging to this grade receive the Certificate of Associateship and have the right to place the letters "A.R.Ae.S." after their name. The grade makes a particular appeal to ground engineers, inspectors and examiners of aeronautical materials, pilots and navigators, those holding commissioned and warrant rank in the General Duties Branch of the Royal Air Force, and foremen of not less than three years' standing. Associates are entitled to the general privileges of membership of other grades. A resumé of the rules dealing with Associates was printed in the February Journal.

Since February, 1926, 53 Associates have been passed by the Council, who feel that the number is a very satisfactory indication of the future success of the new grade which has enabled the Society to widen its scope considerably.

Data Sheets

In February, 1927, the first six Data Sheets of the Society were issued. These sheets contain abstracted information of use to ground engineers, draughtsmen, and all those engaged in the practical side of the industry. Further Data Sheets are to be issued at frequent intervals and will be issued free to all members of the Society who require them. The sheets are printed on an 8×5in. page, convenient for note books, and will enable anyone in the industry to collect together in a condensed and usable form much of the information now scattered in various works of reference, B.S. Specifications, private note books and the like. It is hoped that all members of the Society who have information which may prove useful in this way, will place it at the disposal of the Society with a view to publication. The Council feel that the more widely information is disseminated the more it is to the advantage of industrial and scientific progress as a whole.

Abstracts

Arrangements have been made with the Air Ministry, with the co-operation of the Director of Research, to publish from time to time Abstracts of articles appearing in the world's technical Press and scientific publications. These abstracts will deal with aeronautics and its allied subjects and carry further one of the objects of the Society, to disseminate technical information.

The Journal

The Journal has continued to show increased sales during the year. Its scope is gradually being widened to include more articles and information of use to designers and others. Arrangements have been made, as explained elsewhere, to publish Abstracts from the technical Press and other publications, and it is felt that these will be of great use to members.

A comprehensive and detailed index of the Journal is in the course of preparation and it is hoped that it will be ready during the early part of the summer. This index will give in much greater detail the contents of lectures, articles and other matter which has appeared since its foundation than has yet been found possible.

AERIAL SCIENCE, LIMITED

Balance Sheet,

Dr.	£ s. d.	£ s. d.
To *Nominal Capital*—		
Divided into 20 Shares of 1/- each and 999 Shares of £1 each ...	1000 0 0	
,, *Capital Issued*—		
19 Shares of 1/- each		0 19 0
Sundry Creditors		166 6 8
,, *Subscriptions Received in Advance*		91 9 1
,, *Carnegie U.K. Trust Grant*—		
For Purchase of Books		500 0 0
Expended to 31st December, 1926	465 8 7	
,, *Endowment Fund*		575 0 0
,, *Library Fund*—		
Donations Received	39 16 0	
Less—Expenses for Year	16 1 7	
		23 14 5
International Air Congress—		
,, Funds held by Aerial Science Ltd., on their behalf		60 16 10
,, *Surplus*—		
Reserve Fund—		
Entrance Fees and Life Compositions of present Members, as at 31st December, 1925	2832 12 0	
Receipts for year to 31st December, 1926	85 1 0	
	2917 13 0	
Deduct—Income and Expenditure Account Deficiency at 31st December, 1925 ... ... £1772 9 0		
Less—Excess of Income over Expenditure for year to date 572 19 4		
	1199 9 8	1718 3 4
		£3136 9 4

We report to the Shareholders that we have examined the books of the Society and have of the value put upon the outstanding subscriptions. Subject to this remark, we are of opinion of the Society's affairs according to the best of our information and the explanations given to us

3, FREDERICK'S PLACE, OLD JEWRY, E.C.2.
2nd February, 1927.

Income and Expenditure Account

Dr.	£ s. d.
To Office Rental, Heating, Lighting and Insurance	335 11 5
, Salaries	649 11 1
,, Printing and Stationery	86 9 0
,, Postages, &c....	90 7 8
,, Office Expenses	74 13 4
,, Meetings	65 18 3
,, Journals, Pamphlets, Etc.	250 2 5
,, Audit Fee	18 18 0
,, Income Tax	8 8 0
,, 60th Birthday Celebrations	154 14 5
,, Dinners and Receptions	35 19 6
,, Bad Debts Written off	1 13 6
,, Subscriptions Written off	25 18 0
,, Examination Expenses	3 15 0
,, Excess of Income over Expenditure for Year, carried to Balance Sheet	572 19 4
	£2372 18 11

(The Royal Aeronautical Society).

31st December, 1926.

Cr.	£	s.	d.	£	s.	d.
By *Office Furniture, Printed Books, Bindings, Old Prints, etc.*, as at 31st December, 1925 (including Carnegie Grant—£465 8s. 7d)				803	3	6
,, *Stock of* JOURNALS, *etc.*				389	3	4
,, *Stock of Stationery*...				4	1	0
,, *Sundry Debtors, including Subscriptions owing*				65	13	3
,, *Investments at Cost*—						
£783 6s. 0d. 5% War Stock (Inscribed), 1929/47				725	13	6
,, *Endowment Fund*—						
£700 3½% Conversion Loan at cost	534	18	3			
Cash at Bank	40	1	9			
				575	0	0
,, *International Air Congress*—						
Cash at Bank				64	5	1
,, *Cash at Bank*—						
Deposit Account	500	0	0			
Less—Current Account Overdraft	27	11	6			
	472	8	6			
,, *Cash in Hand*	17	1	2			
				489	9	8
				£3136	9	4

obtained all the information and explanations we have required. We are not in a position to judge that such Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state and as shown by the books of the Society.

(Signed) PRICE, WATERHOUSE & CO.

for the Year Ending 31st December, 1926.

Cr.	£	s.	d.	£	s.	d.
By Annual Subscriptions				1781	3	2
,, Interest on Investments	39	3	2			
,, ,, ,, Deposit	12	4	2			
,, ,, ,, Endowment Fund Investment	21	0	0			
Less—Tax	4	4	0			
	16	16	0			
				68	3	4
,, Donations Received				508	10	0
,, Sundry Receipts (Scottish Branch, etc.)...	20	12	3			
Less—Sundry Expenditure	5	9	10			
				15	2	5
				£2372	18	11

Journal and Sundry Publications

		£	s.	d.
To	Stock, 31st December, 1925	396	7	1
,,	Refunds of Journal payments	3	3	1
,,	Printing of Journal	911	17	0
,,	Postage of Journal	81	11	11
,,	Binding of Journal	10	3	0
,,	Blocks for the Journal	258	17	7
,,	Printing of Advance Proofs	44	3	3
,,	Printing of Reprints	31	16	0
		£1737	18	11

Lecture Programme

1926.

Oct. 7th.—Colonel the Master of Sempill, A.F.C., A.F.R.Ae.S., "Aero Engine Fuels of To-day and To-morrow."

Oct. 21st.—Mr. W. R. D. Jones, M.Sc., "Notes on Magnesium and its Alloys."

Nov. 4th.—Mr. G. F. Mucklow, "Hydrogen as an Auxiliary Fuel for a Solid Injection Engine." (Joint Meeting with the Institution of Automobile Engineers.)

Nov. 18th.—Mr. R. S. Capon, F.R.Ae.S., "Methods of Performance Testing and Analysis."

Dec. 2nd.—Mr. P. B. Henshaw, "Valve Steels."

Dec. 16th.—Wing Commander C. D. Breese, A.F.C., R.A.F., "The Training of Aircraft Apprentices."

1927.

Jan. 6th.—Major B. C. Carter, A.F.R.Ae.S., "Dynamic Forces in Aircraft Engines."

Jan. 20th.—Mr. H. Glauert, F.R.Ae.S., "The Theory of the Autogiro."

Feb. 1st.—Mr. A. H. R. Fedden, F.R.Ae.S., "Supercharging for Aero Engines." (Joint Meeting with the Institution of Automobile Engineers.)

Feb. 17th.—Major R. H. Mayo, O.B.E., F.R.Ae.S., "The Design and Operation of Commercial Aircraft."

Mar. 3rd.—Mr. L. W. Bryant, A.F.R.Ae.S., B.Sc., A.R.C.Sc., and Mr. S. B. Gates, M.A., "The Spinning of Aeroplanes."

Mar. 17th.—Mr. M. A. Giblett, M.Sc., "Line Squalls."

Mar. 24th.—Herr Wronsky, "German Commercial Aircraft Development."

Mar. 31st.—Mr. E. G. Richardson, M.Sc., Ph.D., "Recent Model Experiments in Aerodynamics."

Apr. 7th.—Lecturer and title of lecture to be announced later.

Apr. 28th.—Major R. E. Penny, A.F.R.Ae.S., "Seaplane Development."

May —th.—Professor Prandtl, Wilbur Wright Memorial Lecture.

May —th.—Major Bernardi, "On the Schneider Cup Race."

.—General Nobile, "On Airships."

Informal Discussions

The informal discussions during the year have proved very successful and largely attended. The success of these discussions has been greatly due to Wing Commander T. R. Cave-Browne-Cave, who has been ably assisted by Mr. W. O. Manning and Major R. H. Mayo. The Council and the Informal Discussions Committee learnt with great regret that Wing Commander Cave-Browne-Cave was compelled to resign his position on the Committee in January, 1927, on

Trading Account (Secretary's Statement).

	£	s.	d.
By Sale of Journals	580	2	2
,, Advertisement Revenue	400	0	0
,, Journal Binding	8	12	0
,, Sale of Advance Proofs	13	12	10
,, ,, Sundry Publications	56	9	8
,, Rebate and Discount	39	16	6
,, Stock, C/d.	389	3	4
,, Balance, loss carried to Income and Expenditure Account	250	2	5
	£1737	18	11

taking up his duties at Cardington. His place has been taken by Mr. F. A. Foord, Associate Fellow, of the Air Ministry.

The informal discussions held and arranged for were:—

"The Relative Merits of Water-Cooled and Air-Cooled Engines." Opened by Captain G. S. Wilkinson and Mr. J. D. Siddeley.

"Oil Cooling." Opened by Mr. A. H. R. Fedden.

"Comfort in Aircraft." Opened by Air Commodore J. G. Weir, C.M.G., C.B.E., F.R.Ae.S.

"Materials with Special Reference to Corrosion." Opened by Mr. W. M. Dyson.

Finance

The Council have to report that the improvement in the state of the Society's finances shown last year has been continued. This is largely due to the fact that the Society was still saving in salaries by having an Honorary Secretary. They feel that the finances of the Society are becoming sounder. The deficiency at the end of 1925 was £1,772 9s. 0d., and this has now been reduced to £1,199 9s. 8d., owing to the fact that there was an excess of income over expenditure during the past year of £572 11s. 4d.

During the year the Library has been revalued, and although its value appears in the accounts as the same as in the previous year, in the opinion of the Honorary Librarian this amount is underestimated.

In the Journal and Sundry Publications Trading Account it will be noticed that there is a slightly increased loss which has been due to the increased cost of the Journal during the current year.

On the whole, the Council feel that they can look forward to the coming year with confidence that the satisfactory state of affairs will continue.

Chairman

At a Council Meeting held on June 8th, Colonel the Master of Sempill, A.F.C., Associate Fellow, was elected Chairman of the Society from October, 1926, to September, 1927.

Honorary Treasurer

The Council, for the seventh year in succession, wish to express their appreciation of the advice and assistance received from Mr. A. E. Turner, who has continued to act as Honorary Treasurer.

Honorary Solicitor

Mr. B. Woodward, who has acted as Honorary Solicitor since 1912, has given the Society the benefit of his advice on a number of occasions during the

year, and the Council wish to place on record their thanks for his valuable services so freely placed at their disposal.

Secretary

On 1st May, 1925, Mr. J. Laurence Pritchard, the Editor, became Honorary Secretary of the Society. It was decided to appoint a permanent Secretary on January 1st, 1927, and Mr. Pritchard was appointed.

Staff

The Council have pleasure in recording their great appreciation of the services of the Staff, Miss Olive St. Barbe, the Assistant Secretary, and Miss Barwood.

PROCEEDINGS

Fifth Meeting, First Half, 62nd Session

The Fifth Meeting of the Sixty-second Session of the Royal Aeronautical Society was held in the Theatre of the Royal Society of Arts, 18, John Street, Adelphi, W.C.2, on Thursday, December 2nd, 1926, when Mr. P. B. Henshaw read his paper on "Valve Steels." Colonel the Master of Sempill, Chairman of the Society, was in the chair.

Colonel the Master of Sempill (Chairman of the Society): Before introducing Mr. Henshaw, I should like to say a word in praise of the great achievement of the Italians, who have just won the Schneider Cup race.

Their victory is a really remarkable one when one considers the difficulties incidental to the production of any new types, but especially of those in question. The production of a new machine and engine in such a remarkably short space of time must constitute something of a record, and it is probably not fully realised over here that Signor Mussolini personally inspired the efforts of the firms concerned.

The Italian winner was some 80 m.p.h. faster than its predecessor in last year's race, which was considerably slower than the British entry.

In these circumstances those who questioned the decision that British machines should not compete this year, due to insufficient time being available, have convincing testimony as to the correctness of their views.

I am very pleased indeed to welcome General Guidoni, the Italian Air Attaché, here this evening and to offer him the Royal Aeronautical Society's warmest congratulations on Major de Bernardi's great victory.

I will now ask Mr. Henshaw to give his paper, and I need hardly remind you that he has been for over 20 years the Technical Director of Messrs. Kayser, Ellison and Co.

VALVE STEELS

BY P. B. HENSHAW.

In introducing the subject of valve steels to this Society I do so, not because of any special knowledge which I possess, but on account of the general interest which is being taken in the subject at the present time. It is quite evident that the valve steels which have been regularly used are not satisfactorily meeting all the present conditions, and therefore advances will have to be made, especially as much greater engine efficiencies are being demanded. Presumably the valve has to withstand much severer conditions than formerly. In many cases the result, as far as the valve is concerned, means a higher working temperature, which in turn affects many other properties of the steel such as scaling, the tendency to air-harden, etc.

Whilst one can predict with some certainty the type of valve steel which will suit any engine where the working temperature does not exceed 750°Cent., the matter becomes more difficult when dealing with higher temperatures. The different behaviours of a given valve steel in similar engines working above 750°Cent. is often very puzzling to the metallurgist, and probably equally strange to the engineer. Some of the factors which decide the best steel to use are, for many of us, rather obscure, and we seek your help in advising us on these

engineering matters, so that we may give you the best possible steels for any particular engine.

From this standpoint I propose to consider the properties of valve steels in general use to-day, and to point out the possible lines on which development is likely to take place.

In the first place it might be as well to consider what the properties of a good valve steel are, so that we may form some idea how far those we shall consider conform to the desirable conditions. Dr. Aitchison,* who had a very fine opportunity of considering this question, gave the following list of the properties which a valve steel should possess :—

1. The greatest possible strength at high temperatures.

2. The highest possible notched bar value.

3. The capacity of being forged easily.

4. The capacity of being manufactured free from cracks, whether these arise in the manufacture of the steel bar or are produced during the forging of the steel.

5. The capacity of being heat-treated easily, regularly and reliably.

6. The least possible tendency to scale, and if scaling does occur, the scale should be as adherent as possible.

7. The ability to retain its original physical properties after frequent heatings to high temperatures followed by cooling to normal temperature, also after being heated to an elevated temperature for a considerable length of time.

8. No liability to harden when cooled in air from the temperature which it will attain when used normally as a valve in an engine.

9. The capacity of being heat-treated after forging so that it is free from strains liable to produce distortion.

10. Sufficient hardness to withstand excessive wear in the stem.

11. The capacity of being hardened at the foot of the stem with considerable ease if necessary.

12. The capacity of being machined easily and satisfactorily by ordinary methods.

It will be readily agreed that this is a very comprehensive list and whether or not these conditions meet all the requirements, they certainly emphasise many of the desirable points, and any valve steel possessing all these qualities would be remarkably good and worthy of designating by all the extra-super, etc., prefixes so often associated with ordinary material.

Of course, the importance attached to any particular property will depend on the conditions under which the steel is required to work, *e.g.*, in the case of an engine which never runs above 650°Cent. it is no use condemning as a valve steel one which air-hardens at 850°Cent., although it might be dangerous to use such a steel in an engine running at 900°Cent.

The analysis of the steels used in the various experiments to be described are found in Table I.

They do not call for much comment as they represent types of valve steel which are more or less familiar to all aeronautical and automobile engineers.

The 3 per cent. nickel chromium and the chrome steels have been made in the electric furnace, the others are products of the crucible process. It will be noted that the stainless steel is rather higher than usual in silicon, but the amount contained has not materially altered any of the physical properties which are associated with this class of steel with silicon below 0.5 per cent.

* Paper read before the Institute of Automobile Engineers, November 5th, 1919.

The silicon chrome steel contains an addition of tungsten, but the tests obtained with it are comparable to similar steels without this element present.

The carbon in the cobalt chrome steel is rather high, but no appreciable difference has been found with a similar steel containing carbon 1.25 per cent.

TABLE I.

ANALYSES AND TREATMENTS OF STEELS USED.

STEEL	ANALYSIS.									TREATMENT	
	C.	Si.	Mn.	Cr.	Ni.	V	W	Co	Mo	HARDENING	TEMPERING.
3% NICKEL CHROME.	.43	.25	.45	75	2.8					780°C. OIL	625°C OIL
STAINLESS STEEL.	.40	.89	.44	13.0						950°C. OIL	700°C. AIR
SILICON CHROME.	.54	2.5	.69	8.2			1.56			1000°C. AIR	800°C. AIR
CHROME STEEL.	.61	.34	.40	9.58	•					950°C. AIR	700°C. AIR
COBALT CHROME.	1.50	.42	.27	15.25				3.7	.72	950°C. AIR	750°C. AIR
HIGH SPEED STEEL.	.73	.16	.18	3.78		.5	18.9			950°C AIR	800°C. AIR
HIGH NICKEL CHROME	.45	1.75	.65	12.67	12.81		2.1			NORMALISED, 800°C	
	.40	1.83	1.46	13.2	22.5		3.1				
	.45	1.47	.59	11.9	19.0						

The high nickel chrome steels are representative of a type of Austenitic steels, the properties of which are similar. Whilst differences have been observed in the physical properties of the three steels shown, they all conform to the same general properties and the differences are not very marked. Most of the work has been done on the first of these three steels, and unless otherwise stated the tests given refer to this steel only.

All the steels, after cogging into 2½in. square billets, were rolled down to 1⅛in. diameter round bars, and were then given the treatment stated in Table I.

TABLE II.

TENSILE TESTS PULLED COLD

STEEL	TENSILE TEST				BRINELL	IZOD IMPACT FT. LBS.
	ELASTIC LIMIT. TONS	MAX. STRESS. TONS	ELONG. ON 2" %	RED. OF AREA %		
3% NICKEL CHROME	48.5	56.5	23	62.5	255	66
STAINLESS STEEL	47	48.3	24	58.1	228	50
SILICON CHROME	51	63	21	40	302	9
CHROME STEEL	42	54	24.5	55	228	28
COBALT CHROME	42	58	13	22	255	4
HIGH SPEED STEEL	46	61	15	24	269	5
HIGH NICKEL CHROME	42	68	27	45	269	55

These treatments, it will be observed, do not differ from those usually given to material of similar composition. Experience has proved that they leave the steel in a suitable condition for use, although considerable modifications do not alter their subsequent properties when used as valves.

The mechanical properties of the steels after being subjected to heat-treatment given are shown in Table II.

The somewhat low Izod impact figures obtained with silicon chrome, cobalt chrome and high speed steels need not trouble us at this stage of our discussion. The low ductility of the cobalt chrome and high speed steels are, of course, usual.

It is quite obvious that the strength of the valve at the highest working temperature to which it will be subjected during its working life is of great importance, and will therefore be dealt with at some length. The figures which are given in this paper have been obtained by heating a test-piece of the material to the required temperature. When this was attained, a soaking period of thirty minutes was allowed in all cases, after which the test-piece was pulled, whilst of course still in the furnace, at the correct temperature. The rate of pulling was the same for all the test-pieces as far as this could be arranged. Generally, four minutes was taken for this purpose, except in those cases at the higher temperatures, where the steel elongated more than usual.

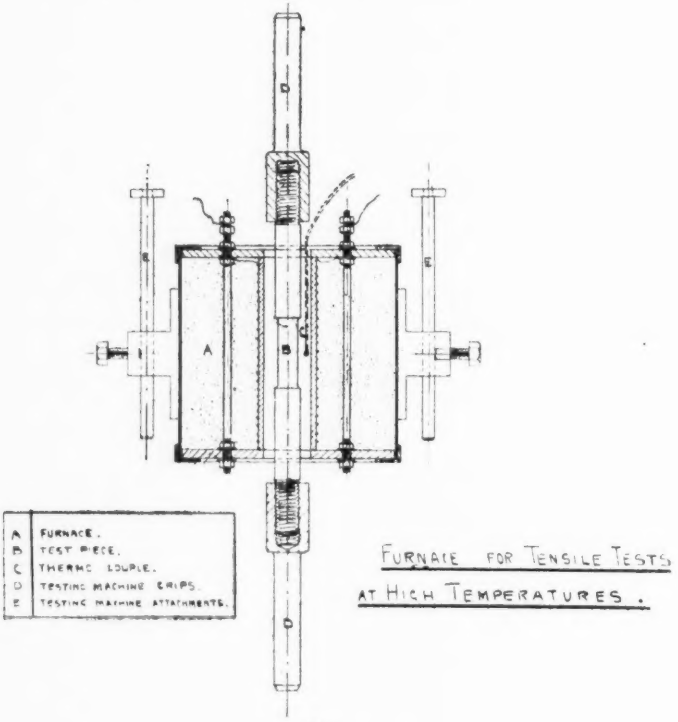


FIG. 1.

The furnace used for heating the test-piece is shown in the sketch (Fig. 1), which needs little explanation.

The furnace was wound in such a way that an equalised temperature could be obtained for the whole length of the reduced test-piece. This portion was the hottest part of the furnace.

The pyrometer was so placed as to be opposite, and practically touching, the central portion of the test-piece.

The temperatures at which the tests were taken may be considered accurate to within ± 5°Cent. The size of the test-piece in every case was 0.564in. diameter

with a parallel length of 2in. No precautions were taken to keep air from the furnace. The two ends of the furnace, where the test-piece came through, were loosely packed with asbestos rope, in order to prevent a current of air being drawn through the furnace, and to keep in the heat.

TABLE III.

HEAT-TREATMENT before Machining Test-Piece					ANALYSIS								
	°C		°C		C.	Si.	Mn	S.	P.	Ni.	Cr.	W.	V.
Oil-hardened	850,	tempered	575		0.30	0.12	0.54	0.024	0.038	0.51	0.14	...	...
,, ,,	850	,,	600		0.45	0.37	0.79	0.022	0.024	...	0.02	...	...
,, ,,	830	,,	600		0.25	0.11	0.36	0.031	0.026	3.63	0.55	...	...
,, ,,	925	,,	650		0.26	0.39	0.17	0.066	0.016	0.39	14.68	...	...
Annealed	800		...		0.60	0.28	0.23	0.044	0.029	...	3.49	14.09	0.72
...	...		...		0.54	0.73	0.10	0.032	0.030	69.9	15.50	...	...

ANALYSIS AND TREATMENT OF STEELS USED BY J.H.S DICKENSON

In considering the strength of material at high temperatures, it will no doubt occur to you all that time must play an important part in the values obtained. This is especially so at the higher temperatures. It will probably be advisable to consider the point in some detail before examining the ordinary tests.

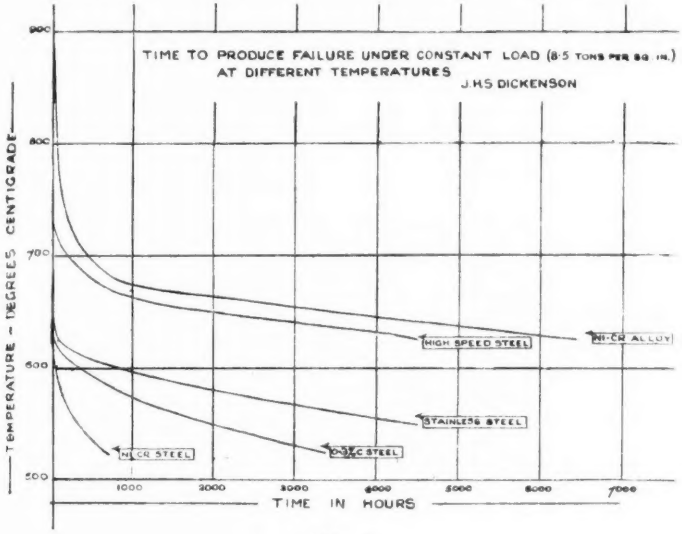


FIG. 2.

Mr. J. H. S. Dickenson, in that very valuable and painstaking research, the results of which are to be found in the *Iron & Steel Institute Journal* No. 2, 1922, page 103, has given us exceedingly useful information on this point.

The steels and alloy with which he dealt, together with their treatment, are seen in Table III.

Three of these steels are of similar type to those we shall study. The nickel chrome alloy is much higher in nickel, and was used by Dickenson in the annealed and as-cast condition.

His programme was to keep these steels under a constant dead load of 8.5 tons per square inch and at 625°Cent., and other temperatures, until a breakdown occurred or it appeared unnecessary to continue. Further pieces were placed under the same dead load of 8.5 tons per square inch and heated at a uniform rate of 100°Cent. per hour until fracture occurred.

The results of the first tests are seen in diagrammatic form in Fig. 2, from which it is found that above 500°Cent., given time, a steel will break at any stated temperature under a load very much less than it would sustain for a more limited period.

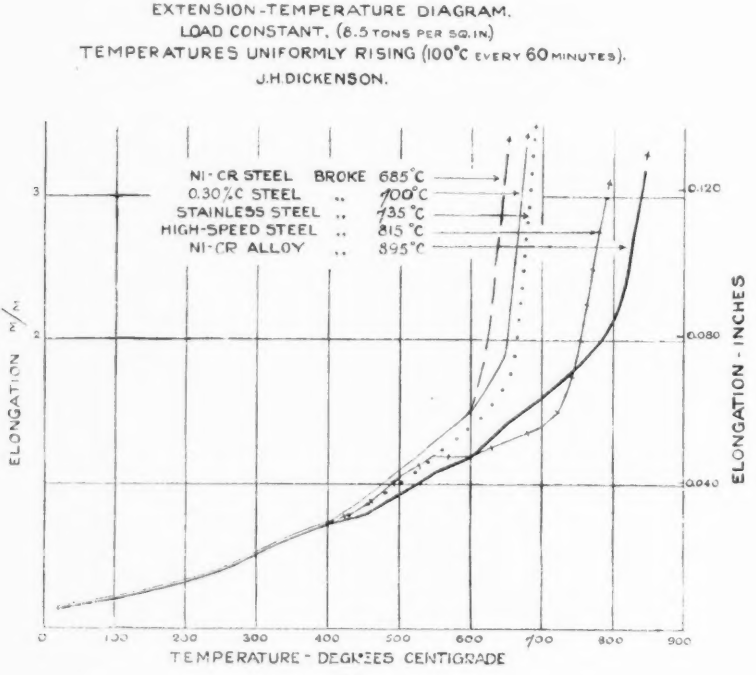


FIG. 3.

In Fig. 3 we see the results obtained by the second method, keeping the load constant and uniformly increasing the temperature.

Dickenson found that whilst high speed steel, pulled quickly at 700°Cent., possessed a tensile strength of 23 tons per square inch, yet when a load of 8.5 tons was maintained at a temperature between 650 and 700°Cent., the piece broke in 564 hours.

In a similar way the high chromium steel only maintained this load of 8.5 tons per square inch for 79 hours, although its strength when tested quickly was 17.4 tons per square inch. One of the most remarkable results given by Dickenson is that of the nickel chromium alloy, which, when loaded as above at 600 to 650°Cent., extended continuously from the first day, although it only broke

after 6,041 hours. Tested in the ordinary way at this temperature the tensile strength was 33 tons per square inch—truly an amazing difference.

Whilst due regard must be paid to this aspect of the question, yet the tests obtained under the conditions stated in the paper do give comparative values for the different steels which are borne out in actual practice. It certainly means that under prolonged heating the strength will not be nearly so high as one would be led to expect, but this will apply to all the steels and will probably flatter those having the lowest tensile strength.

One point might be suggested here which may be worth some consideration. It will have been noticed by all of you how quickly a valve cools down when the engine is shut off. In one or two seconds the valve becomes black, although it may previously have been working at 850°Cent. Providing the valve has not been long enough at the high temperature to actually yield at all, the cooling down to more or less normal temperatures will be tantamount to commencing

TABLE IV.

TENSILE TESTS AT HIGH TEMPERATURES.								
MAXIMUM STRESS - TONS PER SQUARE INCH.								
STEEL	600°C	650°C	700°C	750°C	800°C	850°C	900°C	950°C
3% NICKEL CHROME	34.0	23.6	13.5	11.2	9.2	6.9	4.5	-
STAINLESS STEEL	24.2	17.3	10.2	8.0	6.1	5.6	7.9	-
SILICON CHROME	42.0	34.5	25.3	17.8	10.7	7.2	3.9	3.0
CHROME STEEL	36.5	30.0	19.0	13.0	7.0	7.2	7.3	5.2
COBALT CHROME.	45.0	30.5	24.8	13.6	10.0	5.8	8.1	6.0
HIGH SPEED STEEL.	41.0	26.6	21.3	16.8	9.8	7.7	8.5	5.6
HIGH NICKEL CHROME.	42.6	38.3	33.8	28.6	24.0	19.4	15.0	12.5

with a fresh valve, which presumably will have a similar length of life to that which it possessed before being heated.

In order to make my meaning clearer, let one suppose that a given valve will work continuously at a temperature of 850°Cent. for 15 hours before elongating in any way. If worked for more than this time, creep sets in and the valve would consequently be defective and breakage might easily result.

Now suppose that instead of working up to the full limit of fifteen hours the engine was temporarily shut off after twelve hours, immediately the valve cools down, and it is fair to presume that on starting up again it would work for another fifteen hours continuously before failing to maintain its value as a valve.

All the test-pieces received a previous treatment as given in Table I. Commencing at 600°Cent., tests were taken in intervals of 50°Cent. up to 950°Cent., beyond which temperature it was not thought necessary to go. Unfortunately, there was not sufficient material left of the 3 per cent. nickel chrome and the stainless steel to do tests at 950°Cent. Tests from other bars of similar analyses show that at this temperature the tensile strength falls, at a similar rate to the other steels.

An examination of the diagram Fig. 4, which contains these tests in graph form, will show that all the steels exhibit a somewhat rapid falling off in the tensile strength with increased temperature.

The high nickel chrome steel has a more gradual fall than the others and appears to drop at a more uniform rate.

All the steels which possess pronounced air-hardening properties, with the exception of the silicon chrome steel, show a rise in tonnage at 900°Cent. In the cases of the stainless and cobalt chrome steels this is very noticeable. The strength of the silicon chrome steel falls appreciably at 900°Cent. In every case the strength is lower at 950°Cent. Evidently the fact that the silicon chrome steel does not air-harden until a temperature just above 950°Cent. is reached, accounts for the difference between it and the other air-hardening steels. The

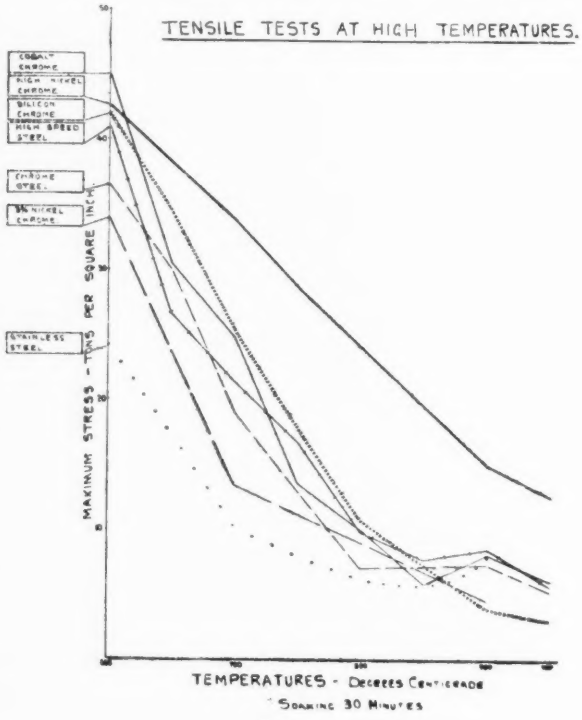


FIG. 4.

results obtained by Aitchison and also Dickenson in their papers already referred to, followed a similar course to those given here.

Whether any of these steels have an elastic limit at temperatures above 500°Cent., the author is not prepared to say.

A stress-strain diagram taken on a piece of high nickel chrome steel similar in analysis to the first, given in Table I., is seen in Fig. 5.

This was taken on a piece pulled at 900°Cent.; the elastic limit is stated to be 12.82 tons per square inch, but this is probably somewhat high.

Considering the high temperature at which this piece was being pulled, the diagram indicates a steel which one would expect to maintain its strength for fairly long periods, so long as the stress was not unduly high. This is in agreement with the findings of Dickenson.

For comparison, a stress-strain diagram was taken under similar conditions of the high speed steel which is included in the same diagram (Fig. 5).

The ductility of this series at various temperatures as measured by the elongation and reduction of area needs little comment. The figures obtained when pulled at 850°Cent. and 900°Cent. are to be found in Table V.

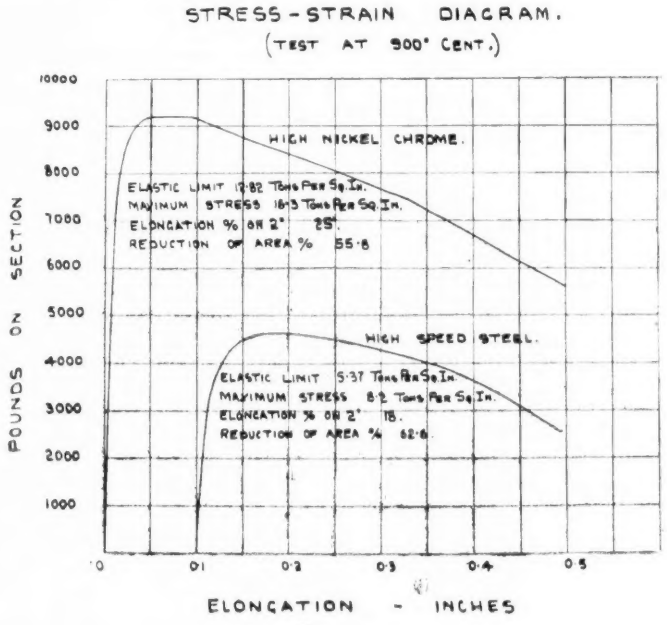


FIG. 5.

These again point out the stiffening effect of the air-hardening steels at 900°Cent. This is noticeably seen in the elongation which, it will be observed, shows a very great reduction, being less than half in the case of the stainless and the cobalt chrome steels, and almost as great with the high speed steel.

TABLE V.

TENSILE TESTS AT 850°C AND 900°C

STEEL	TEMP.	MAX. STRESS	ELONG. % ON 2"	RED. OF AREA	BRINELL BEFORE TEST
3% NICKEL CHROME	850	6.9	...	...	...
	900	4.5	50.0	89	286
STAINLESS STEEL	850	5.6	46.0	90	286
	900	4.9	21.0	83	
SILICON CHROME	850	4.2	55.0	94	293
	900	3.9	56.5	98.5	...
CHROME STEEL	850	4.2	...	...	...
	900	4.3	20.0	81	286
COBALT CHROME	850	5.8	43.0	71	269
	900	8.1	14.0	64	
HIGH SPEED STEEL	850	4.4	43.0	83	277
	900	8.5	28.5	72	
HIGH NICKEL CHROME	850	19.4	30.0	72	269
	900	15.0	28.0	72	

The reduction of area is not very seriously affected. Generally, the elongation was confined to the reduced portion of the test-piece, but in certain cases this spread to the shoulder.

All the steels used have air-hardening properties with the exception of the high nickel chrome group. As the 3 per cent. nickel chrome steel can only be

TABLE VI.

BRINELL HARDNESS TESTS AFTER REHEATING TO TEMPERATURES STATED

STEEL	HARDENING		REHEATING TO (COOLING IN AIR) DEGREES CENTIGRADE												
	TEMPERATURE	BRINELL	300	400	500	600	700	750	800	850	900	950	1000	1100	1200	1250
3% NICKEL CHROME	780°C. OIL	534	477	375	321	262	241	255	262							
STAINLESS STEEL	950°C. AIR	534	534	534	534	311	262	241	212	444	477	555	555			
SILICON CHROME	1000°C. AIR	555/534	534	534	534	430	340	302	302	286	262	340	534			
CHROME STEEL	950°C. AIR	512	512	495	495	293	229	217	212	418	477	512	555			
COBALT CHROME	950°C. AIR	555	555	555	555	402	302	286	286	477	534	600	600			
HIGH SPEED STEEL	1240°C. AIR	662	627	627	627	627	477	351	321	512	600					
HIGH NICKEL CHROME	NORM^{D} 800°C.	255/277							269	269	269	262	255	207	179	167/170

used for inlet valves or those running at low temperatures, it is only likely to air-harden under very abnormal running, where failure would probably take place due to lack of strength or excessive scaling. Actually it air-hardens to a Brinell hardness of 321 at 900°Cent.

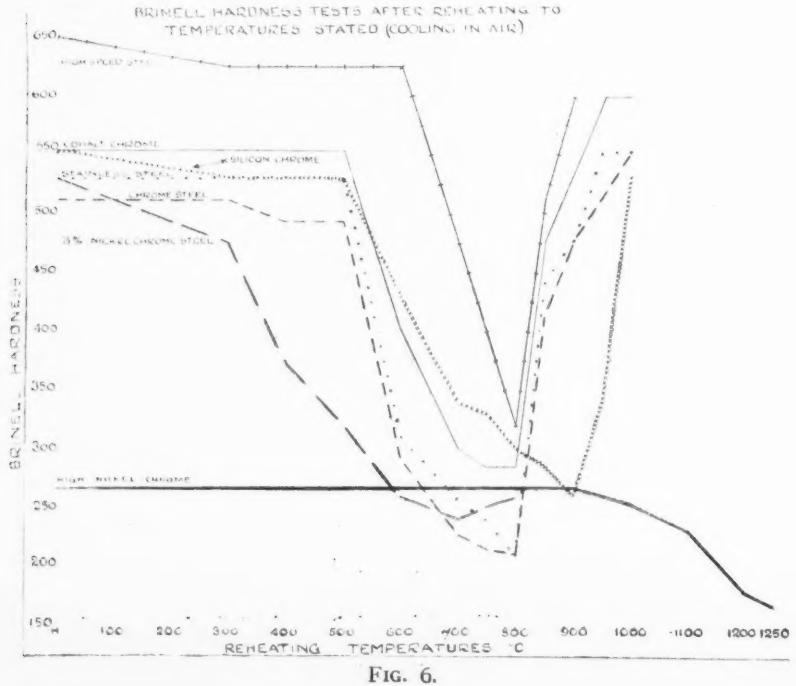


FIG. 6.

The effect of heating the steels to various temperatures and then allowing to cool out in the air is seen in Table VI.

All the samples were previously air-hardened at temperatures stated, except the 3 per cent. nickel chrome steel, which was oil-hardened, and the high nickel chrome steel, which was normalised but cannot be said to have been air-hardened as it has no capacity to do so. This type of steel retains its hardness after normalising up to 1000°Cent., and at higher temperatures actually becomes softer with a corresponding enlargement of the crystal structure.

It will be observed that the high speed steel retains its hardness up to a higher temperature than any of the others.

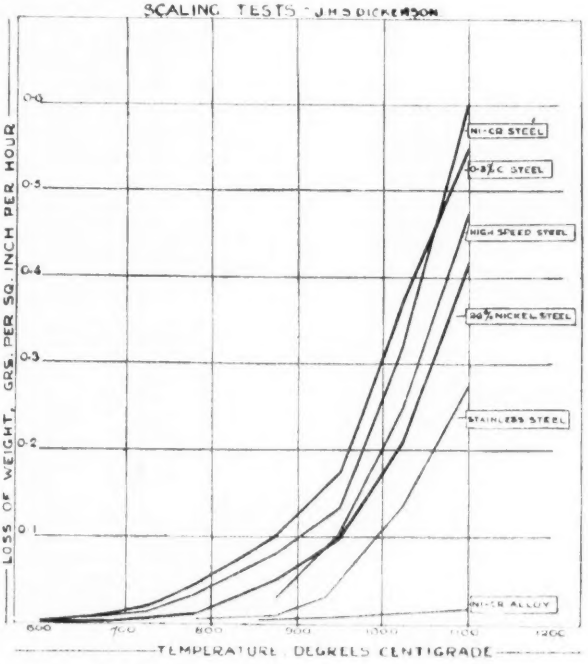


FIG. 7.

All the air-hardening steels, with the exception of the silicon chrome, reach the lowest hardness at 800°Cent., and at 850°Cent. they have all begun to stiffen again. It will be noted that the silicon chrome steel begins to harden a little at 950°Cent., and is fully hard when cooled from 1000°Cent. This higher temperature at which air-hardening takes place is, no doubt, a valuable property of this type of steel.

These results are seen in diagrammatic form in Fig. 6, which brings out the various points quite well.

Perhaps the two most important considerations are the inability to air-harden the high nickel chrome steel and the high temperature necessary before the silicon chrome steel air-hardens.

The temperature at which the steels air-harden is, of course, dependent on the temperature of the Ac points. These can be seen from the expansion curves,

Fig. 10, which will be found to correlate with the increase of strength shown by several of the steels between 850 and 900°Cent.

It must, of course, be a great advantage for a valve to possess very considerable resistance to oxidation at working temperatures.

Many published results on the scaling of different steels at high temperatures are available. Those given by Dickenson in his paper are seen in Fig. 7.

These are fairly typical of other results and show how, in most cases, the scaling rapidly increases with rising temperature, except in the case of the nickel chrome alloy. Many tests have been made on the steels considered in this paper, under varying conditions, and at temperatures up to 1070°Cent. The results are

TABLE VII.

SCALING TESTS AT 1000° CENT.
AFTERWARDS COOLING IN AIR.
TEST PIECE – CYLINDER ·750" DIA. × 2" LONG.

STEEL	LOSS OF WEIGHT PER SQUARE INCH PER HOUR.
SILICON CHROME.	·0258 GRAMMES.
HIGH NICKEL CHROME.	·0563 "
COBALT CHROME.	·1418 "
STAINLESS STEEL.	·2197 "
CHROME STEEL.	·2985 "
HIGH SPEED STEEL.	·3983 "

rather erratic, no doubt due to the different conditions; yet although the amount of oxidation varied in different tests at the same temperature, all the figures obtained (above temperatures of 700°Cent.) placed the steels in the same order in respect to their scaling properties.

However, one or two points stand out quite clearly in all the tests made. First of all the 3 per cent. nickel chrome steel very readily scales at temperatures as low as 650 to 700°Cent. The high speed steel was found to be good until temperatures of 725 to 750°Cent. were reached, when the rate of scaling increased very considerably and became heavy at 850°Cent. Apart from the 3 per cent. nickel chrome steel, the high speed steel is easily the worst from the standpoint of scaling at the higher temperatures.

The stainless steel resists scaling very well up to 825°Cent.; afterwards it scales somewhat heavily.

The chrome steel, as one would expect, does not resist scaling so well as the stainless steel, although it is distinctly better than the high speed.

The steel most resistant to scaling is the silicon chrome. This keeps very free from scale up to 1000°Cent. At the lower temperatures the surface remains bright. The high nickel chromium steels are also highly resistant to scaling up

to 950°Cent. The slight scale formed at high temperatures is very adherent and is not likely to break away in work.

In Table VII. will be found figures showing the amount of scale per square inch per hour, of pieces tested at 1000°Cent. in a gas furnace, under rather adverse conditions. The test-pieces were in the form of cylinders and measured 0.75in. round and 2in. long.

Impact tests were made on all the steels except the 3 per cent. nickel chrome and stainless. The test-pieces were turned to the standard B.E.S.A. Specification, using the round form of test piece 0.45in. diameter.

An Avery Izod impact machine was used for the tests, having a special gripping arrangement; this ensured the test-pieces being very quickly gripped, thus preventing any undue loss of heat. The furnace was close to the testing machine and the arrangements enabled all the tests to be taken in the same time. Two tests were made at each temperature; the close agreement of the duplicate figures seen in Table VIII. shows that the testing was carried out under very similar conditions. The temperature of the 200°Cent. series was actually 230°Cent.

TABLE VIII.

NOTCHED BAR TESTS (IZOD) AT HIGH TEMPERATURES.

VALUES GIVEN IN FOOT LBS.

STEEL	TEMPERATURES - DEGREES CENTIGRADE.									
	15°C.	100°C.	230°C.	300°C.	400°C.	500°C.	600°C.	700°C.	800°C.	900°C.
SILICON CHROME.	4	7-8	18-18	38-35	37-36	36-35	38-38	55-45	73-76	77-78
CHROME STEEL.	37	70-69	77-77	77-79	77-76	77-79	70-73	69-78	74-75	74-74
COBALT CHROME.	5	11-12	15-13	15-15	13-13	13-15	14-12	15-16	17-16	20-22
HIGH SPEED STEEL.	6	12-13	17-17	20-20	19-5-19-5	22-21	22-22	22-22	19-20	31-32
HIGH NICKEL CHROME.	32	45-40	35-36	31-33	27-28	28-25	24-27	26-25	28-27	30-30

The figures obtained from the test-piece of the high nickel chrome steel when broken cold were distinctly lower than usual. As this was not discovered until all the hot tests had been made, the test-pieces were examined, when a small unsoundness was seen. This was present in all these particular test-pieces, so that probably the actual figures for this steel are low, but it is quite evident this has not affected the relationship of the tests at the various temperatures.*

A glance at Fig. 8 will show that the impact figures, in all the steels save the nickel chrome, are higher at any temperature up to 900°Cent. than at room temperature. In the case of the nickel chrome steel it is only slightly lower.

The most surprising result is that of the silicon chrome steel. This type of steel is known to give a low notched bar value at ordinary temperatures, and, whilst it was natural to look for some improvement at the higher temperatures, it was not expected that the increase would be so great. The value for the chrome steel which at normal temperatures is good, increases at 100°Cent. to nearly double, and maintains this increased resistance almost constant throughout the whole range of temperatures.

* Subsequent tests proved this. The results follow those given at a greater value throughout.

In every case there is a distinct improvement at a temperature as low as 100°Cent. Except for the high nickel chrome steel, the value is practically doubled.

It might be noted in the case of the silicon chrome and chrome steels the test-pieces, at temperatures 800 and 900°Cent., were not actually broken; they were simply bent over by the weight of the pendulum, there being only a slight tear at the bottom of the notches.

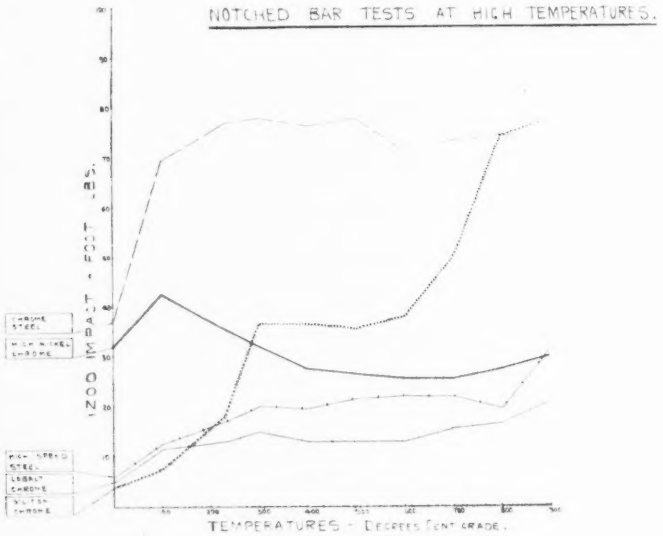


FIG. 8.

The results seem to point out that the only danger of breaking a valve, due to a low notched bar value, is on starting up from the cold, especially when the valve has acquired considerable hardness due to cooling down quickly from high working temperatures. In this case the air-hardened valves would only have an Izod value of one or two ft.-lbs., and would not improve as quickly as the tests in Fig. 8 show, as in this latter case all the test-pieces were previously treated as Table I., which treatment includes a tempering high enough to obtain a relative degree of toughness.

The approximate temperature necessary to overcome this maximum brittleness will be seen to be as follows:—

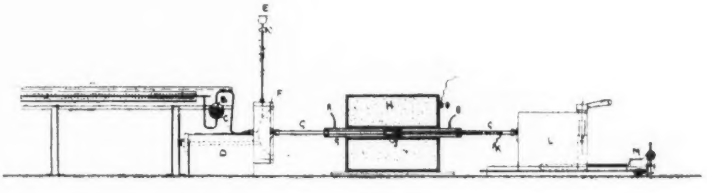
Steel.	Temperature.
3 per cent. Nickel Steel	500°Cent.
Stainless Steel	600°Cent.
Silicon Chrome Steel	700/750°Cent.
Chrome Steel	600°Cent.
Cobalt Chrome Steel	700°Cent.
High Speed Steel	750/800°Cent.

From this standpoint the high nickel chrome steels have a distinct advantage in that they never air-harden and therefore a low impact value is never reached.

It may be of some interest just to look at the expansion of the various steels.

Fig. 9 shows the dilatometer used for this purpose. It is similar to that of Andrews, Rippon, Miller and Wragg (*Iron & Steel Institute Journal*, 1920, No. 1, page 527), afterwards modified by Griffiths (*Iron & Steel Institute Journal*, 1923, No. 2, page 133). The cast-iron block L can be quickly unclamped to allow for the insertion and removal of the test-pieces and silica tubes. The micrometer adjustment M is useful for finally adjusting the pressure on the diaphragm F, and also for calibration purposes.

The curves in Fig. 10 have all been adjusted to allow for the expansion of the fused silica tubes used as thrust rods. The measurements obtained represent the increase on the length of the hollow cylinder. The heating was done without exhausting the air or using an inert gas. In this way the results correspond more nearly to what would occur in actual use. The time taken to heat from the cold to 900°Cent. was two hours.



A	MICROMETER SCALE.
B	WATER.
C	MERCURY.
D	LEAD BLOCK (2 CWTS.
E	WATER INLET.
F	STEEL DISC.
G	SILICA TUBES.
H	FURNACE.
J	TEST PIECE.
K	THERMO COUPLE.
L	CAST IRON BLOCK FOR ROUGH ADJUSTMENT.
M	MICROMETER FINE ADJUSTMENT.
N	GAS INLET.
O	GAS OUTLET.

DILATOMETER.

FIG. 9.

The high nickel chrome steel has a greater expansion than any of the others and except for a small halt at about 400°Cent., expands almost uniformly.

All the other steels with a lower rate of expansion, increase at almost the same rate as each other until just over 500°Cent. is reached, when they begin to diverge.

The Ac point commences at about 800°Cent. (with the exception of the silicon chrome steel) when a considerable contraction takes place. This reaches its maximum between 850 and 875°Cent., after which expansion again takes place.

The silicon chrome steel passes through the same changes only at a higher temperature.

On cooling the reverse conditions obtain, the steels gradually contract until the Ar point is reached, when a sudden expansion is experienced at temperatures somewhat lower than those found on heating. The high nickel chrome steel contracts in a regular manner without showing any periods of expansion.

Evidently in using high nickel chrome steel some recognition of its greater coefficient of expansion will need taking into account in order to prevent the sticking of the valves in the guides.

It would be interesting to know whether the expansion and contraction at the change points play any considerable part in the efficiency of the valve at work. These effects may suggest a probable cause for difficulties experienced.

From various tests we have considered it will be apparent that the high nickel chrome steels possess many properties which would lead one to believe they represent a suitable type from which to make valves for high temperature work. Practical tests on a very large scale have certainly proved that under the most severe conditions they have worked very well indeed. Whilst these steels cannot yet be said to have reached the perfection desired, they mark a step in advance and point out a probable line of future development. It may therefore be well to consider their properties and behaviour a little more fully.

All the steels we have before us offer certain difficulties in forging and stamping, with the exception of the 3 per cent. nickel chrome steel which is fairly easy to work, especially with the large experience of this class of steel by most forgers and stampers.

In general, steels which retain a large amount of their tensile strength at high temperatures must, of necessity, be harder to work, they require more force to produce a given alteration in the section of the forging. This may only mean the utilisation of a larger hammer or drop stamp providing the material will stand the work expended on it. It generally means that less work can be done at any one operation and so calls for a little more care than with the weaker types of steel.

All these steels can be worked without much fear of failure when care is used.

The air-hardening properties of several of the steels introduce another difficulty which needs carefully watching. When a stamping is made out of such steels in a way which allows any work to be put on the material after it has cooled (in the dies or otherwise) below the point at which it has air-hardened, then bursting or cracking is almost sure to take place, either at once or on subsequent heating.

There are many other well-known points attendant on the air-hardening properties of the steels which require watching, but they are such as every efficient forger or stamper knows and practises.

In actual valve-making I think one of the more difficult steels, out of which to produce good stampings, is the silicon chrome. Why this should be so I cannot say. The high nickel chrome steel is not difficult to work so long as the heating for forging is not unduly hurried, and the temperature is carefully regulated.

From experience gained in making valve forgings I would place the steels in the following order, the first being the easiest to work :—

1. 3 per cent. nickel chrome steel.
2. High nickel chrome steel.
3. Chrome steel.
4. Stainless steel.
5. Cobalt chrome steel.
6. High speed steel.
7. Silicon chrome steel.

It may be a surprise to find it stated that the high nickel chrome steels forge so well. This requires a little explanation; a great deal depends on governing the forging temperature rather more exactly than is general for other steels. When forged either too hot or too cold, trouble is bound to result, as of course it does with all steels, only to a more limited extent. When once the correct working temperature is found and adhered to, stampings may be made having a regularity of physical properties which leave little to be desired.

Variation in the composition of this type of steel will naturally call for some variation in the treatment; the details which follow have, therefore, reference to the first of such steels given in Table I.

The best heating temperature lies between the limits of 1050 and 1100°Cent. When temperatures in excess of 1150°Cent. are used, the steel does not work well and is, in fact, very likely to burst and fall to pieces. When the forging

TABLE IX.

HIGH NICKEL CHROME STEEL.

TESTED AT 900° CENT.

HOW ROLLED	ELASTIC LIMIT. TONS PER SQUARE INCH	MAXIMUM STRESS. TONS PER SQUARE INCH	ELONGATION % ON 2"	REDUCTION OF AREA %	BRINELL HARDNESS AS ROLLED	BRINELL HARDNESS NORMALISED
HOT	9·27	15·7	24·5	52·9	223	269
ORDINARY	12·82	16·3	25·0	55·8	255	269
COLD	9·27	12·45	31·0	69·0	277	248

heat is as low as 950 to 1000°Cent. it is difficult to forge the valves to size, and in order to do so excessive work is necessary which will produce a certain amount of cold work and most likely strain the steel, especially in the neck of the valve—generally the weakest part. When forging too cold the die is nearly certain to lose its shape and become enlarged. It is astonishing how near to temperature a forger who understands his work can keep his furnace and there-

TABLE X.

HIGH NICKEL CHROME STEEL

EFFECT OF NORMALISING AT VARIOUS TEMPERATURES.

TEMPERATURE	IZOD IMPACT FOOT LBS.	BRINELL HARDNESS
800° CENT.	52 - 57	269
900° CENT.	60 - 57	269
1000° CENT.	60 - 62	255
1100° CENT.	66 - 66	207
1200° CENT.	105 - 113	179
1250° CENT.	116 - 120	167

fore regulate the heat at which he works. When once he has found the correct working temperature, then, without the aid of a pyrometer, he will not vary from the correct range, providing he has a suitable furnace.

Some effects on the mechanical properties of the steel, due to variations in the working temperature, are seen in Table IX.

The bars in this case were rolled from 2½in. square billets down to 1¾in. round. The bar marked "ordinary" was rolled at the usual temperature of 1100°Cent. The bar styled "hot" was taken to nearly 1200°Cent., and the other marked "cold" rolled from 975°Cent.

The bars, after cooling down from rolling, were all normalised at 800°Cent., and afterwards tested at 900°Cent.

The figure given for the elastic limit, as previously stated, may be high, but is lower than the yield point. The stress-strain diagram for the ordinary rolling is included in Fig. 5. The advantage of the correct working temperature

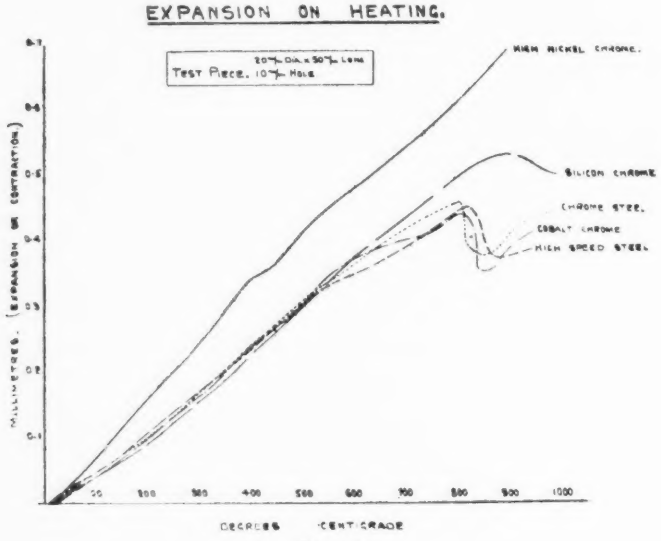


FIG. 10.

is at once seen in the higher ratio of elastic limit to the maximum stress, and, whilst the bar rolled from the low heat has nearly the same ratio, the strength is nearly four tons less.

It is rather curious to observe the greater ductility as the temperature of rolling falls. This is quite appreciable in the case of the bar forged cold, although of course associated with a lower tensile strength. The alteration in the Brinell hardness will be seen to rise, after normalising, quite appreciably in the bar rolled hot, and less so in the normal bar, whilst the bar rolled colder has become softer. This is always the case with this material when hot-worked below the correct temperature.

It has already been seen that this type of steel does not air-harden when cooled from high temperatures. On the contrary it becomes softer and also has a greater notched bar value, as will be observed from Table X.

The structure of the pieces normalised at 800°Cent. and 1200°Cent. are seen in Figs. 11 and 12, which show how the crystal grains have grown and the excess carbide has mainly found its way to the cell walls.

This type of material is not easy to cold-draw. It work-hardens, and the surface tends to pull out and so tear the dies and prevent further drawing.

To show the effect of cold work, a piece of rolled bar 1.135in. diameter was, after normalising at 900°Cent., reduced .0035in. in size by cold-drawing. The Brinell hardness increased from 269 to 302. After normalising at 800°Cent.

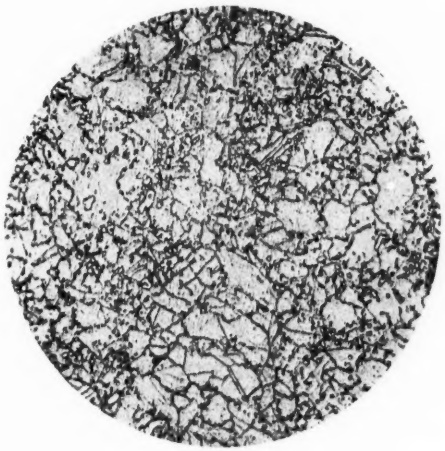


FIG. 11.

High Nickel Chrome Steel, normalised at 800°C., magnified 300 diameters.

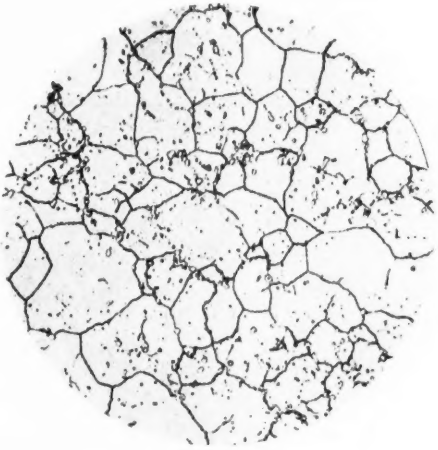


FIG. 12.

High Nickel Chrome Steel, normalised at 1200°C., magnified 300 diameters.

(the Brinell hardness being 269) the piece was pulled hot at 900°Cent. and gave the following test :—

Maximum-stress tons per sq. in.	Elongation in 2in.	Reduction of area.	Brinell Hardness.
16.00	20.5 per cent.	53.2 per cent.	269

This piece was from the same bar as the test seen in Table IX. marked "ordinary," and shows that the only effect appears to be a slight loss in ductility.

The structure of the material after cold-drawing is shown in Fig. 13. It is very streaky; the excess carbides are drawn out into lines, and here and there are seen large bands almost free from such carbides, similar to that seen running

FIG. 13.
High Nickel Chrome Steel, cold-drawn, magnified 100 *diameters.*

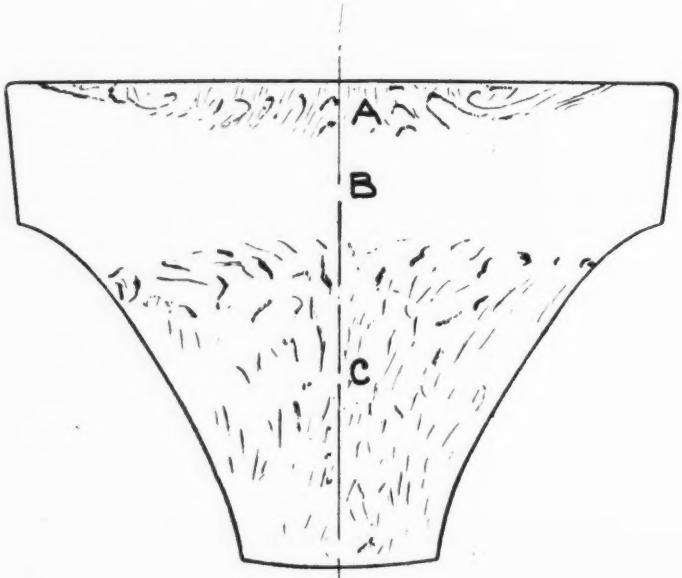


FIG. 14.

across the centre of the photograph. Whilst normalising at 800°Cent. improves the structure a little, it requires a higher temperature to effect much alteration.

In examining a valve which has been made by first drawing the stem from a round bar and then up-ending the head in a die, a zone is produced between

FIG. 15.

High Nickel Chrome Steel, forged hot, zone B, magnified 300 diameters.

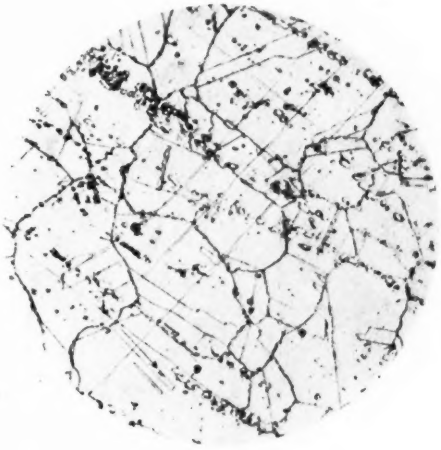


FIG. 16.

High Nickel Chrome Steel, forged ordinary heat, zone B, magnified 300 diameters.

the top of the head and the bottom part of it, which, in a macro etching, appears nearly structureless. As it is difficult to take a very convincing print from such a piece, the sketch (Fig. 14) will give a diagrammatic idea of the different zones.

To show this effect more fully, three valves were made—one forged at a

high temperature (1180°Cent.), another forged at the correct temperature (1100°Cent.), and the third forged too cold, at 975°Cent.

To take the case of the zone B, which, when etched, appears to the eye almost structureless, it is found that in this position the structure exhibits, under

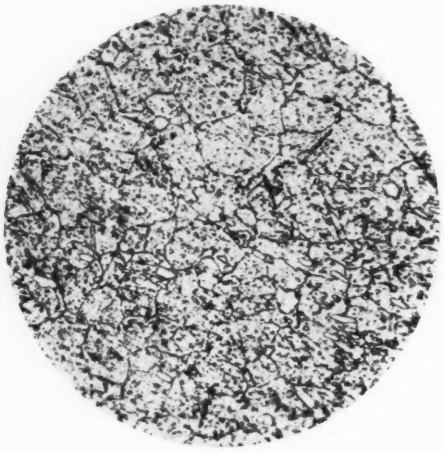


FIG. 17.

High Nickel Chrome Steel, forged cold, zone B, magnified 300 diameters.

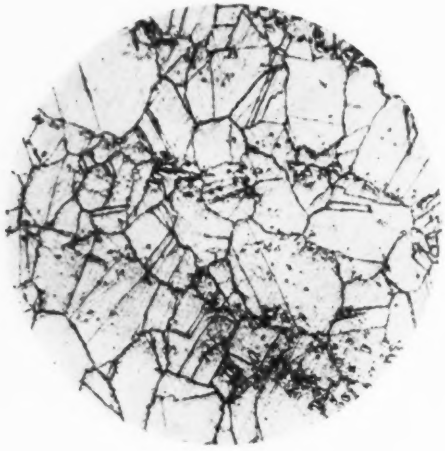


FIG. 18.

High Nickel Chrome Steel, forged ordinary heat, zone A, magnified 300 diameters.

the microscope, the largest crystal grains, and these vary very much according to the temperature of forging. Microphotographs of this zone taken from the valves forged hot, correctly and cold are seen in Figs. 15, 16 and 17.

The section from the hot-forged valve (Fig. 15) shows portions of four or five crystals, whilst the cold-forged one (Fig. 17) has approximately twenty-five times as many, the correct forging containing an intermediate number.

The zones A and C of the correct forging have a structure as seen in Figs. 18 and 19.

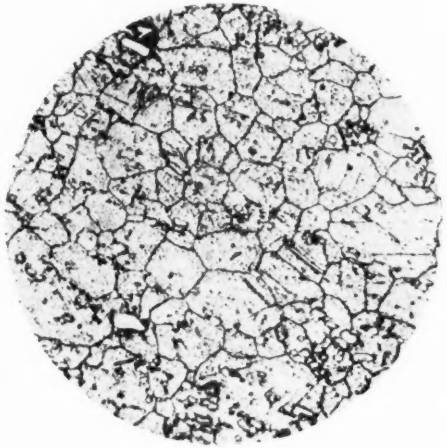


FIG. 19.

High Nickel Chrome Steel, forged ordinary heat, zone C, magnified 300 diameters.

FIG. 20.

High Nickel Chrome Steel, as cast, magnified 50 diameters.

The hot-forged valve has a rather poor structure in the stem, whilst the cold-forged one shows considerable crystal distortion and a generally poor structure.

The structure of this material as cast can be seen in Fig. 20.

There are really two structures which have etched up and the photograph is

a compromise of the two. If it be held in a good light ten or twelve inches from the eyes, the pattern will appear fairly uniform over the whole area, but if the distance be increased to three or four feet, a second and larger structure can be seen. The dendritic structure found here has a very great tendency to persist, no matter what the treatment may have been, nor how much work may have been performed on it. It can generally be traced in most sections examined, but it has not been found to correlate with any particular properties and does not seem to be any cause for concern.

One of the difficulties which is found in Austenitic steels is connected with certain machining operations—notably drilling.

Speaking in a general way, the operations of turning, milling, etc., do not offer any serious trouble; in fact, they can be done with comparative ease, but sawing and drilling are more difficult matters. This is really due to the work-hardness which the steel so readily develops, and any precautions which prevent it taking place or lessen its amount render these machining operations so much easier. It is therefore imperative that drills, etc., used on this steel must cut and not merely force the material off. The cutting angles of tools should be more acute and as much clearance as possible seems to be a necessity.

Whatever difficulties may be attached to machining, they are not such as cannot be overcome when once the cause of them is realised.

The ends of valve stems made from the high nickel chrome steels cannot, of course, be hardened. It is no use trying any intensive case-hardening compounds to attain this, as any case so formed will not harden any more than does the original material.

As a result of the inability of making the end of the stem hard, it becomes advisable to fit some form of hardened thimble over the end. This does not offer any serious disadvantage as it is regularly done with success.

Many valves have run satisfactorily leaving the end of the valve stem without any thimble. In such cases the end has evidently become superficially hard due to work. Although such hardness cannot be readily measured, being superficial, it is quite sufficient under certain conditions to resist wear and enables the end of the stem to retain its shape and size.

Attention has already been called to the somewhat greater expansion of the high nickel chrome steels as compared with the usual valve steels. It is an easy matter to allow for this. Even when this is done, it must be recognised that any Austenitic steel is liable to have a somewhat poor wearing surface. There is always a tendency to pick-up on the stem. This can be lessened by having the surface as highly polished as possible.

In view of this the material used for valve guides calls for some care in selection. At present various experiments are being made, but it is too early to say much of the results. In some cases a hard phosphor-bronze has worked exceedingly well. On the other hand cast iron of a very close grain but containing a considerable amount of finely-divided graphite has proved good, probably due to the fact that, to some extent, it is self-lubricating.

Such in brief are the general properties of the valve steels in use to-day, with a suggestion, confirmed by actual practice on a large scale, that the high nickel chrome type of steel possesses advantages which are certainly worthy of our consideration.

The author, in concluding, would like to express his thanks to Mr. J. Pashley and the other members of his staff at Messrs. Kayser, Ellison & Co. Ltd., who have done so much of the work.

Discussion

Colonel the Master of Sempill: Before asking Mr. Henshaw to reply I would like to make a few remarks on this very important subject so admirably expressed by the Lecturer. His paper will be of great value as a reference, and brings all existing data into line.

The development of the aero engine has conferred great benefits on all other users of internal combustion engines. It will probably be no exaggeration to say that the study of Poppett valves, and the materials therefor, is the most important contribution that has been made.

There can be no doubt of the need for further research, but at the same time, those of you who are like myself, believers in the advent of the single sleeve valve engine, may see a solution of these problems in that direction.

At the commencement of the war there were some 23 different brands of valve steel in use. The majority of the users had no more knowledge of the physical properties of these various materials than the names conveyed; if troubles arose they just changed the brand until something better was found.

A process of weeding out was started at once and all steels obviously of no use were discarded. From this work eventually arose the five Air Board specifications that were in force for many years. It is interesting to see from Mr. Henshaw's paper how different the ideal specification is from say five years ago.

I wonder if Mr. Henshaw has considered the corrosive effect of various dopes now employed to an increasing extent to raise the H.U.C.R. of petrol; I refer, of course, mainly to those metallic substances of which tetra ethyl lead is the best known.

This, and other such substances in their pure form, have certain definite disadvantages which may in a large measure be overcome. Even so, troubles have been met with when using, for example, iron carbonyl as a dope, due to the deposition of metal on valve stems, etc.

It is possible that certain valve steels now in use may be less prone to attack, and it would be interesting to hear the Lecturer's views.

Mr. A. H. R. Fedden: Referring to the properties of a good valve steel, as set out at the beginning of the paper, I would like to lay special stress on points 4 and 9. I think that other engine constructors will probably be familiar with an experience which is rather prone to disappointment, viz., samples of a new valve steel for an experimental engine are obtained from the steelmaker which give most excellent results, but when a production order is placed for this steel, manufacturing difficulties in producing a quantity of regular forgings prevent the steel being used. It is of vital importance on such a part as a valve, which is submitted to continual heating and cooling, that the material should be clean and free from forging defects.

With reference to the tensile tests at high temperatures, at the present time there is unfortunately no standard method of carrying out tensile tests at elevated temperatures with the result that any group of figures are only inter-comparable, since the values obtained depend upon the rate of pull as the Author has shown by means of Dickenson's very valuable research. Obviously, such laborious methods cannot be applied to routine testing and it would be of really great assistance if some standard rate of pulling could be agreed upon so that all published results of tensile tests at elevated temperatures will be standard.

At the Bristol Engine Works, we apply the load at the rate of one ton per square inch per minute, which differs from the Author's rate of pulling, and we find that all our results on similar steels are three or four tons per square inch lower.

With this is bound up the creep stress, which may be defined as that stress which if applied to the test piece for an indefinite period will not produce continuous extension. Taking the Author's assumption that cooling down to normal temperature restores the valve as far as its tendency to creep is concerned, then taking six hours as a normal continuous flying time for an engine, would it not be better to adopt in valve steel specifications a stipulation that the test piece must not show any creep when subjected to a definite load for a period of eight hours at a constant high temperature.

It would be of value to be able to correlate the creep strength with a relatively rapid tensile test, but so far experiments would appear to show that the ratio between ultimate tensile strength (by the rapid method) and the creep stress not only varies according to the temperature, but also according to the type of valve material. This much, however, is known, that it is not always safe to design on the maximum stress obtained by a rapid test. Perhaps the Author could give his opinion on this question for a suitable test for valve steels.

The Author has obtained a large amount of very useful data and it would have been of great interest if he could have obtained fatigue tests on these tests at elevated temperatures in order to determine the real value of the creep stress and ultimate stress.

Bound up with the question of valve guides is the question of thermal conductivity as, although the heat of the valve is dissipated chiefly through the valve seat, a fair quantity is also disposed of through the valve guides. Unfortunately, the high nickel chrome type of steel has only about one third the heat conductivity of ordinary steel and this in itself will cause the valve to run at a higher temperature and consequently we lose a portion of the increased strength of this type of valve steel due to this reason, so that it is imperative to use material for the valve guides with the highest possible thermal conductivity. Cast iron and cast phosphor bronze have the same fairly low value, so that in discovering a valve guide material which will overcome the inherent tendency of this type of steel to pick up on the stems, it is really essential to use one which has a high heat conductivity, otherwise the cumulative effect of low heat conductivities will detract from the value of this steel for high temperature duty valves.

The Bristol Company have carried out a number of tests with various valve guide materials for high nickel chrome valves without very convincing results. I would like to have Mr. Henshaw's views on the suitability of machining the stems of high nickel chrome valves within about 1/16in. of size, cold working the stems and then finish grinding, in order to endeavour to produce a hardened surface on the valve stem. The grinding finish on a high nickel chrome valve stem is, I consider, of the utmost importance. From the engine maker's point of view, high nickel chrome steel seems so superior to all other brands for exhaust valves that I would submit that the steelmaker should concentrate on this one serious defect in regard to this steel, viz., picking up on the valve stem.

I note with interest that Mr. Henshaw considers silicon chrome steel is the most resistant to scaling; we have not found this so, high nickel chrome being superior in this respect.

I would like to thank Mr. Henshaw for his most exhaustive and excellent paper on valve steels.

Mr. W. D. Douglas: I have listened with great pleasure to the summary of the paper. With reference to the effect on the failing load of rate of loading, we get the same effect with many materials. It is very marked in many organic materials, and the rate of loading is frequently specified where tests have been standardised. There is no difficulty in obtaining a steady rate of loading. With beam machines, the jockey weight can be given a uniform speed along the

beam or the beam can be loaded flowing water or sand while the straining gear is operated to keep the beam floating.

Fatigue tests at high temperatures offer a good many features of experimental difficulty, but where, as in this case, steels are being selected for a particular application it is only necessary that tests should give relative values. Absolute values for fatigue resistance, even when available, cannot very well be used for calculating the life of an engine valve. Various steels might be tested under conditions simulating those which occur in practice and tests of a simple type might be devised which could be made at high temperatures.

Dr. W. H. HATFIELD: I have listened with the greatest of interest to Mr. Henshaw's lecture. We regard him as one of our most reliable metallurgists. He has treated the subject of valve steels in a very satisfactory manner. I am, as you know, associated with another works producing similar steels. I wonder as to what extent the metallurgical aspects of valve steels are at the present, the most important for consideration. I would rather pursue the object with which I came here, namely, to learn something of the views you engineers are holding at the present time of the services of the steels which are available for you. Mr. Henshaw has recapitulated the position and has then put before you the results obtained from the austenitic nickel chrome steels. I am sure that he, as well as myself, would like the engineers to tell us of their actual experiences. A number of you have used these steels and could make valuable contributions to the discussion. There are a good many people who are investigating steels with the sole object of giving you better and better steels. How can we arrange our tests so that they may be a reliable guide to how these steels will behave under service conditions?

Mr. Fedden raised the point of the length of time that the steel is actually at the temperature given in the Author's tables before it is pulled. If the time is shorter or much longer, you obtain a different result from the one you would get if you maintained it there for half an hour. In our experimental work we keep the steel at the particular temperature for half an hour. I should like to know from Mr. Henshaw exactly what the time was in his experiments. Mr. Fedden suggests that tests on valve steels should include a specified creep value. A test of that kind would be of great interest, though I cannot quite see the application to the valve problem.

Silicon chrome steels have been shown by the Author to have had a very useful life and are doing a very useful work in aero engines. His figures are perfectly reliable, but still there are pros and cons for these various steels, and, personally, I am not clear that a case has been made yet against the silicon-chromium steels. The austenitic nickel-chromium steels certainly promise well and merit careful consideration. Such steels admirably resist corrosion from the products of combusion and, at the same time, have high mechanical test values. Their one disability, as pointed out by Mr. Henshaw, is that they cannot be hardened, therefore means will have to be found to insert mechanically portions of dissimilar steel at those points where great hardness is required.

With regard to the scaling tests given in the paper, the Author will admit that the conditions of these tests are somewhat empirical and may involve accidental features capable of seriously upsetting the comparative values. With regard to the austenitic steels, it will be clear that there are so many possibilities in this class that it cannot be assumed that the limited compositions dealt with by the Author, adequately indicate the full possibilities of the series, and no doubt there is room for much further development.

In conclusion he (Dr. Hatfield) would just like to say one more word with regard to the silicon-chromium steel, namely, that whilst this steel is admittedly an air-hardening steel, yet the critical point is at such an elevated position,

owing to the presence of silicon. that air-hardening is not likely to take place under service conditions, and this is in accord with what is actually found in practice.

He (Dr. Hatfield) would like once more to voice his appreciation of Mr. Henshaw's valuable paper.

Mr. T. G. ELLIOT: Mr. Henshaw's paper is of particular interest to me because of the generally excellent agreement between the results he gives and those obtained in the Hadfield Research Laboratory.

The selection of steels given in the paper is admirably representative of the range of valve steels.

The effect of the addition of silicon to the chrome steel would have been more clearly demonstrated had tungsten been absent from the silicon-chrome material, although Mr. Henshaw rather discounts the effect of tungsten in the tests.

The excellent behaviour of the high nickel chromium steel at high temperatures is clearly shown.

I should like to ask Mr. Henshaw what was the duration of the scaling tests at 1,000°C., because in our own experience, working at this temperature, the silicon-chromium steel broke down after about 600 hours, whereas the high nickel-chromium steel did not, the latter thus proving distinctly superior after that time. It would be interesting to know whether Mr. Henshaw's experience confirms this.

Mr. T. H. BURNHAM congratulated the Author on the method of presentation of his paper, namely, giving in the first place a list of the properties of an ideal valve steel and then proceeding to show how far the chief types of steel now being used fulfilled the required conditions. The list was exhaustive, and the only addition that might be made was the resistance of the material to vibration and fatigue at high temperatures. Very little work, however, seemed to have been done on the determination of this property, in fact the only reference known to the speaker was some work by Jasper in America, who found that the fatigue strength of carbon steel above 500°C. was greater than the slow time tensile strength.

As is well known the fatigue strength, at least at ordinary temperatures, appears to be closely related to the tensile strength, and the above remarks might have some bearing on the Author's statement that the ordinary tensile strength at high temperatures gave practical comparative values of the different steels.

The Author's results on silicon-chromium steel made an interesting comparison with a recently published research by Monsieur Grard. The effect of the addition of silicon is to raise the change point, which for 4 per cent. silicon in this type of steel was as high as 1,050°C. With such a steel there seemed to be little fear of air hardening, but other disadvantages were involved, and the optimum silicon content was chosen as 2.5 per cent. M. Grard said that the addition of a small percentage of tungsten or molybdenum increased the hardness at high temperatures, but gave no data in support of this. The speaker would like to ask Mr. Henshaw if he could verify this statement.

In carrying out his tensile tests the Author mentioned that no precautions were taken to keep air from the furnace. This probably was no detriment in short time tests, but for long time tests at high temperatures, with which the Author has also dealt, the effects were not entirely negligible.

The speaker agreed that it would be valuable if some fairly rapid means of determining the creep strength could be devised. He referred to certain empirical methods at present used in France and Germany, but no universally acceptable test appeared available.

The speaker also expressed some surprise at the relative compositions of the silicon-chromium and high nickel-chromium steels in the scaling table, and inquired whether the figures for the nickel-chromium steel referred to specimen No. 1 or No. 2.

As regards the high nickel chromium steels which showed outstanding superiority in most directions, the speaker agreed that a means of increasing the hardness of the stems to prevent picking up would be valuable. He inquired to what degree the Author found the hardness of the stems could be increased by cold working.

In conclusion, he wished to thank Mr. Henshaw for an interesting and valuable paper.

Major B. C. CARTER (*communicated*): Those concerned with engine research and development will welcome Dr. Henshaw's paper as a most valuable contribution to the subject of valve steels. Some of the more important points brought forward in the paper appear to me to be:—

1. That intermittent working may enable a valve to endure which would fail in continuous working.
2. That the permissible working temperature is limited to a definite maximum value, namely, the air hardening temperature, except in the case of a material like the high nickel-chrome which does not air harden.
3. With a non-air hardening austenitic material there is an inherent tendency to "pick up" in the valve guides.
4. That the coefficient of expansion for high nickel-chrome steel approximates to that of aluminium.
5. That the scaling tendency at 1,000°C. is very markedly less for silicon-chrome and high nickel-chrome than for tungsten steel.
6. That one cannot compare the tensile strengths of various valve steels at high temperatures unless they are obtained with the same rate of loading.

The impression obtained from testing engines goes to confirm the truth of item 1, and this point has an interesting bearing on the relationship that should exist between testing conditions and conditions of use. Fortunately aircraft engines are only required to run uninterruptedly for more than a few hours in special cases.

As regards item 2, difficulty has been found in machining valves after they have been running in an engine and this is an indication that considerable hardening can occur without producing immediate failure. The "picking up" tendency with high nickel-chrome valve stems requires more than high polish to overcome it, and one hopes that endeavours to find a satisfactory guide material to use with these steels will meet with success because, apart from this difficulty, they withstand very arduous working conditions, exhibiting neither the scaling associated with tungsten steels nor the stretching to which stainless steel is prone.

The high coefficient expansion of the high nickel-chrome steels is an asset in certain applications other than to exhaust valves.

There is no mention in the paper of thermal conductivity and it is perhaps a moot point whether this is an important property of valve steels.

Taking 100 to denote the thermal conductivity of 3 per cent. carbon steel, I believe the corresponding figure for 5 per cent. nickel steel is 70 and for 30 per cent. nickel steel and 13 per cent. chromium steel about 30. Perhaps Mr. Henshaw could give the figures for the precise materials mentioned in his paper.

The trend of modern design has been towards larger valve stems to obtain improved cooling, and it is possible that for the same design a valve of lower conductivity will run appreciably hotter. The taking up and disposing of the heat is a complex matter however, and a good conducting material may take up more heat and thereby offset a greater facility for getting rid of it. Much can be done by careful valve design towards keeping down exhaust valve temperatures. It is important to extend valve guides as near as possible to the valve head to protect the neck of the valve from the hot exhaust gases. This can be effected better with the mushroom type than with the tulip type of head.

The rise of strength with temperature in the region of 900°C., shown in Fig. 4 of the paper, gave rise to some curious effects in the case of some tests on specimens of refractory material with which I am acquainted. In these tests the temperature was controlled by passing a heavy electric current along the specimen. When the specimen began to pull out at one point the temperature in this region was increased and the extension arrested owing to the increased strength. As a result some specimens developed three or more narrow places before failure.

Mr. Henshaw's Reply.

Before replying to the discussions, I have to thank all the speakers for the far too kind remarks they have made about the paper.

I quite agree with Mr. Fedden that condition numbers 4 and 9 in Dr. Aitchison's list of desirable properties for valve steels are very important. With the experience which has been gained in forging and stamping the steels dealt with, there should be little difficulty in completely fulfilling these conditions.

Comparatively little testing has been carried out at high temperatures so that the point Mr. Fedden raises was bound to arise. The results obtained by different experimenters will therefore vary somewhat. The results given in the paper are, of course, only true when the conditions stated are observed, although these conditions were made such as could be repeated in everyday testing.

The test suggested by Mr. Fedden might be satisfactory and would possibly pick out the better of two steels, both of which, under ordinary hot testing, are good. At present the subject is in its infancy and much more work will require to be done before we can say very much.

No fatigue testing has been done by the Author at high temperatures. The difficulties are rather considerable and such testing would probably be undertaken best by one of the special research institutions like the National Physical Laboratory. Probably the results would only be of academic interest.

Whilst it is true the high nickel-chrome steels have a less heat conductivity than ordinary steels, this fact is not likely to appreciably affect the temperature at which the valve is working. So far as observations have been made there is very little difference when the working temperature is in the region of 800° Cent. At much lower temperatures probably the difference would be more noticeable, but in that case the strength of all the valve steels considered is ample.

No doubt Mr. Fedden is right when he suggests that the valve guides should have the highest possible heat conductivity.

As the austenitic steels work harden to a considerable extent, so that a hardness up to Brinell 400 can be obtained, it would seem a very desirable procedure to adopt Mr. Fedden's suggestion and machine the stems over size and then cold swage them to the finished dimension, if possible without final grinding, so as to preserve the cold worked surface which will undoubtedly resist wear much better than one produced by grinding.

Mr. Douglas has emphasised the point raised by Mr. Fedden with regard to a standard rate of loading for tests taken at high temperatures. Eventually some standard method will be adopted. I am much obliged for the suggestion made.

As previously stated fatigue tests at high temperatures offer considerable difficulty to the ordinary laboratory, and so far little or no work has been published on this point. If, as Mr. Douglas suggests, fatigue tests of a simple type could be carried out under conditions simulating those occurring in practice, they would prove interesting and might reveal facts which would be very enlightening.

It is interesting to find Dr. Hatfield in such agreement with the results presented in the paper. The point he emphasises is of importance. We, from the metallurgical side, often fail to produce the most satisfactory steel because of our lack of knowledge of all the conditions, and any help from the engineering standpoint will help us very considerably.

The time the test pieces were maintained at the respective temperatures was, in all cases, 30 minutes. This agrees with the period used by Dr. Hatfield.

The scaling tests are only given to indicate the approximate relationship of the various steels in this particular. The actual results will vary in magnitude according to the conditions under which the tests are made, but under all the conditions used the *order* of the steels in their scaling properties has remained the same.

It is interesting to find that the results put forward in this paper are in such close agreement with those obtained by Mr. Elliot.

The time for the scaling tests given was only for a comparatively short period, but after a more prolonged period of 144 hours the silicon-chrome steel was still superior to all the others.

I am obliged to Mr. Elliot for the information that after 600 hours at 1,000° Cent., he finds the silicon-chrome steel breaks down. This result is rather to be expected.

The Author has, however, been surprised to find how resistant to oxidation the silicon chrome-steel was.

In reply to Mr. Burnham, the statement made by M. Girard is probably correct. All the results so far seem to prove that tungsten or molybdenum do increase the hardness of silicon-chrome steels at high temperatures.

The scaling tests on the high nickel chromium steel referred to the first of the three shown in Table I.

The Chairman has raised an interesting point which will probably need more consideration than has been given to it. From all available data there seems little doubt that the austenitic nickel-chromium steels will withstand the actions of the metallic dope better than the other steels, but as so little consideration has been given to this aspect of the subject no definite information can be given.

PROCEEDINGS

SIXTH MEETING, FIRST HALF, 62ND SESSION

The Sixth Meeting of the Sixty-second Session of the Royal Aeronautical Society was held in the Theatre of the Royal Society of Arts, 18, John Street, Adelphi, W.C.2, on Thursday, December 16th, 1926, when Wing Commander C. D. Breese, A.F.C., read his paper on "The Training of Aircraft Apprentices." Colonel the Master of Sempill, Chairman of the Society, was in the chair.

Colonel SEMPILL: Those of you who were present at the Society's Reception a short time ago will remember that the honour of Honorary Fellowship was conferred on Sir Alan Cobham, and Life Associateship on his mechanics, Sergeant Ward and Mr. Capel. The commemoration of the outstanding work as a ground engineer that had been accomplished by the late Mr. Arthur Buller Elliott was under consideration. At a meeting of the Council of the Royal Aeronautical Society a few days ago it was eventually decided that an annual prize be given to the value of five guineas for competition amongst the apprentices under training at Halton. The subject of the paper would be decided by the Commanding Officer at Halton in collaboration with the Chairman of the Royal Aeronautical Society.

Wing Commander Breese, who is going to lecture to us this evening, is in charge of the technical training of all those apprentices at Halton, and I should like him on his return to inform them of this decision. Mr. Elliott started as a mechanic in the Royal Air Force, but after the cessation of hostilities he was demobilised and joined the Instone Air Line. After serving with this line for some time he left to join the De Havilland Aircraft Company, and it was not long before he embarked with Mr. (now Sir) Alan Cobham on some of his earlier long flights. The first flight of note was the flight to India and back with Sir Sefton Brancker, Director of Civil Aviation, as a passenger. Then followed the flight to South Africa and back, which led up to the flight to Australia and back—a flight which very nearly came to a finish after the death of Mr. Elliott in the Middle East. There were, of course, many other flights where the success achieved by Sir Alan Cobham was very largely due to the wonderful work of the late Mr. Elliott. I need only mention two—the flight to Tangier in a day and the King's Cup Race of 1924.

When Wing Commander Breese is explaining the purpose of the Elliott Memorial Prize he would, I think, do well to draw attention to the late Mr. Elliott's great attention to detail. This trait was very largely responsible for the success of the enterprises with which he was associated. You will all have heard as to how he became wounded in the air and the long flight that was necessary before any landing could be effected. When, eventually, a landing was effected, the late Mr. Elliott was nearly unconscious from loss of blood and the agony of being lifted out of the machine. In spite of this he was sufficiently conscious when being placed on the stretcher to warn Sir Alan Cobham to see that the oil supply to the engine was turned off.

Many of you here this evening will have met the lecturer before, and will have approached him as I myself have done with trepidation. I refer to the time when Wing Commander Breese was responsible for the technical examination of all officers who wished to join the R.N.A.S. or the R.F.C. before the War and during the first years of the War. Anyone unable to answer satisfactorily the mass of technical questions that he poured out had every cause for

feeling extremely uneasy. Wing Commander Breese was one of the first naval officers to join the R.N.A.S., which he joined as an Engineer Lieutenant. His period of service has been almost entirely taken up with the training of technical personnel, and so you can realise that we are listening to someone whose experience of this important subject is probably without equal in the Royal Air Force to-day.

THE TRAINING OF AIRCRAFT APPRENTICES

BY WING COMMANDER C. D. BREESE, A.F.C.

It is with considerable diffidence that I find myself about to address you to-night upon the subject of the Paper, which is "The Training of Aircraft Apprentices." I say with considerable diffidence, firstly, because I realise how very important to the future of aeronautical practice is this question of the preliminary training of mechanics, and secondly, because my own practical experience of this subject is limited to a few years.

I hope that some of those who will take part in the discussion, after the reading of the Paper, will correct any mis-statements I may make in connection with civilian apprentices and will be able to put before you such problems as are peculiar to that side.

(*a*) *Importance*

There can be few people in the world to-day, and certainly no members of this Society, who do not believe that very rapid expansion of the science and practice of aviation is a certainty. If this expansion is not to be hindered, two things are essential, firstly, the brains to foresee, to design and to direct; and secondly, the practical skill to construct and maintain.

It is with the training necessary to produce the practical skill that we are dealing to-night.

(*b*) *Numbers*

Until comparatively recent years the number of aircraft apprentices trained has been small. Prior to 1914 civilian firms, almost without exception, employed men whose craftsmanship had been learnt in some other trade. Similarly the Service requirements were met by volunteers from among the other ranks and ratings of skilled Service trades.

Since then, however, the practice of taking a boy when he is young, but quite unskilled, and then training him on certain definite lines with the specific idea of making him an aircraft mechanic has progressed steadily forward.

To-day, I believe, there are a number of firms who employ 200 or more apprentices. As the period of apprenticeship is five years, this represents a yearly output of forty skilled mechanics from each such firm. In the Royal Air Force the period of training is three years, and as there are 3,000 apprentices under training at the present time, the yearly output is approximately one thousand.

It must be remembered that this latter output, which is a large one, will be completely absorbed by the Royal Air Force for the next seven or eight years, and practically so for the ten years after that.

Before going into the details of training systems, it is necessary to have a clear perception of the personnel whose training we are to consider.

An aircraft apprentice may be taken to be a lad between the ages of 14 and 18 years, who is anxious to acquire the knowledge and skill-of-hand which will enable him to become a practical aeronautical mechanic.

These lads are recruited from various sources, but all enter upon their training with the one idea of making the skill and practice of aeronautical mechanics their life's work.

In the case of civilian apprentices, the boy may be the son of an employee of the firm, or one from outside, whose interests and ambition lie in aeronautical work. He obtains an introduction or recommendation to the firm and, if upon an interview he is thought suitable and there is a vacancy, he is taken on for a probationary period of three to six months. If he proves satisfactory during that time he proceeds along the normal course of five years' apprenticeship.

In the case of Service apprenticeship, entry is by competition in qualifying examinations. These examinations are held twice each year and are of three kinds:—

1. An open competitive examination conducted by the Civil Service Commissioners.
2. A limited competitive examination organised by the Air Ministry for boys who are nominated by some recognised body such as the Local Educational Authorities, Council of the Boy Scouts' Association, etc.
3. An examination for candidates whose parents are in the Service.

When the results of the examinations are published, successful candidates are invited to attend before a Board of Officers for medical examination and attestation. After passing this, they enter upon the three years' course of intensive training at Halton.

Differences Between the Service and Civilian Training

Before proceeding further, I think it would be well to point out some of the fundamental differences between the Service and civilian apprentices.

Firstly, Objects of Training

The object of the three years' intensive training, as applied by the Service, is to produce a mechanic who will be able to maintain and repair a large number of different types of aircraft aero engines. To do this he must possess a high degree of skill in all the processes utilised in repair work and a thorough knowledge of the principles of construction, assembly and operation of many different units.

The civilian training, on the other hand, is directed towards the production of a mechanic having sound knowledge of a number of the processes of repair and production as applied to *one* type of engine or aircraft. As, however, his livelihood and income are dependent upon his skill, and as a higher grade of skill and therefore wage-earning power can only be acquired by specialising on one process, it is possible that the result of the training will be that he will concentrate on one particular process as applied to one type. He must be proficient in various processes, or able to make himself so very quickly, so that in times of either stress or slackness he may be able to fill various positions in the shops, but in the general average he will adapt himself to the one process most to his liking.

Secondly, Systems of Training

The Service training is essentially an intensive one. The brain and skill of a boy, who has already enough knowledge to pass the competitive entrance examination, is developed along certain lines with the sole object of making him an aircraft mechanic best fitted to meet Service requirements.

Civilian training, on the other hand, is not intensive, but rather dependent upon the boy's own energy and application, to seek for and acquire—rather than have thrust towards him—the knowledge and skill necessary for a good mechanic.

Time is too short to allow me to deal further with the principles, and I will now pass on to details of the systems of training.

Considering the Service system of training first. The boy, between 15 and 17 years of age, enters the Royal Air Force School of Technical Training at Halton, and according to the position which he obtained in the competitive entrance examination he is allocated to the trade of his choice. After a period of three weeks spent in letting him settle down into Service routine, learning the rudiments of discipline, drill and marching, barrack-room procedure, etc., his technical training begins. The first year of this is devoted to teaching him the basic principles of his trade and the skilful use of tools. The working hours are divided into half-day periods, $4\frac{1}{2}$ hours in the morning and 4 hours in the afternoon. Two-thirds of these working hours are spent in the workshops and one-third in the school, the two syllabuses of instruction being arranged so as to dovetail into one another. In this way the practical and theoretical sides are taught simultaneously, and the monotonous labour of learning the ground work of a skilled trade is lightened. It is the monotony which is found to be the greatest factor in causing a boy to lose interest in the work. Under the three years' intensive training system, it is essential that interest and keenness shall be maintained.

There is very little compulsory evening work. In the workshops the apprentice is led progressively through a series of 20 to 30 exercises, according to his trade. Every boy has to complete a satisfactory example of each exercise, but the quicker and more adaptable are able to do so without many failures. These are given further more advanced exercises and additional time in the machine shop.

At the end of the year the boy knows his tools, can keep them in good order and use them with considerable accuracy and in the majority of cases quickly.

From the first he is taught to read from blue prints working drawings, and in every instance to make personal rough sketches of the work in hand.

During the first year in school he is taught the ground work which will enable him to assimilate the higher courses which are given during the last two years in conjunction with the advanced workshop instruction. This ground work is built upon the foundation of his earlier education. It consists of the fundamental facts of mechanics, heat, electricity and magnetism, and is designed to lead to advanced courses on the internal combustion engine, the strength and properties of aircraft materials, the theory of structures and the elementary theory of flight.

The eight hours spent in school each week is divided among the various subjects approximately as follows:—

Two hours drawing.
Two hours general studies (history, literature, etc.).
Four hours science and mathematics.

Records of the boy's progress in the workshops are kept on cards, and these are written up at three-weekly intervals. These records show assessments of his industry, practical ability, progress, hours lost, etc., and also the results of intermediate *viva voce* examinations.

At the end of the year a practical test and written examination are held, and an attempt is made to eliminate those boys who are unable to reach the necessary standards.

Up to this point all fitters receive the same instruction and all carpenters. Upon the results of the examination and the boy's choice, a further specialisation is made, in the case of fitters, into aero engine fitters, armourers and motor transport fitters; in the case of carpenters, into carpenter riggers, motor body builders and pattern makers.

After this specialisation each trade follows a special syllabus.

The following year is devoted to teaching the detail of the special subjects of the trade. Periods of from three to six weeks are spent upon each subject. In the case of the aero engine fitter, for example, the forms are of a class of ten working in a bay with two engines of a certain type. These are dismantled, sketched and notes made of various parts, connections, etc., and the engine finally re-erected. It is then installed in a fuselage by the class and run. If the class is a quick one, instruction in timing and adjustment is given. At the end of the three or six weeks, the boy's progress is assessed and he passes to another type of engine, or to the carburettor or ignition bays.

During the first eight months of the third and last year, the apprentice concentrates upon the repair of those engines, the general characteristics of which he learnt in the previous year. Live engines as distinct from instructional ones are utilised and every endeavour is made to inculcate those principles of accuracy and reliability so essential in this work. A period is spent in the bearing shops where he learns and practises the running and fitting of bearings.

The final four months is spent in revision of the entire course, both by lectures and by practice; weak points are strengthened and additional instruction given on those subjects which may have been curtailed by sickness, leave, etc.

During the whole of the last two years of the course it is essential that the skill-of-hand acquired during the first year shall not be lost. To this end half a week each month is devoted to practical bench work. In the past, the exercises carried out during these periods have been similar to but more advanced than those worked during the first year. Now, however, it has been decided to substitute for these exercises work upon actual engine parts, these being obtained from scrap material. In point of fact this amounts to teaching the apprentice the application of his skill to actual requirements.

On the carpentry side, the second year is devoted to teaching the general characteristics of aircraft, the rigging and trueing up of these, fabric work and doping, the splicing of cables and advanced carpentry. The classes are arranged so that no instructor has more than ten boys.

In the first half of the last year instruction is concentrated upon repair and construction. It is not easy to obtain sufficient examples for repair. Each entry of 160 to 200 apprentices builds a number—three or four aircraft, complete from the blue prints, all timber parts being cut from the raw material. The boys make their own jigs for rib construction, bending, etc., and every part carries the name of the boy or pair of boys who made it and the time taken.

One entry constructed three Avros, the next three Grebes, and three Bristols are now in hand.

The material used is—for the sake of economy—condemned aircraft timber, therefore the machines can never be flown, but otherwise they are in all respects exactly to specification. The apprentices are very proud of this work, the machines being subsequently utilised for rigging instruction.

As in the other trades the final period is devoted to revision.

All trades spend three weeks at the aerodrome. Here they learn the handling, cleaning and maintenance of aircraft and engines, the swinging of propellers, taxying, filling up and methods of salving crashed aircraft.

Every boy is taken up for a flight, and in the case of those who are particularly keen, two or three. Flights are also given as rewards for particularly good conduct, behaviour, or progress.

School

From the examination at the end of the first year, to the commencement of the revision period, the instruction given in the school moves side by side with the advanced work in the workshops.

Briefly, it covers the internal combustion engine, the strength and properties of materials, the theory of structure and elementary theory of flight.

Running throughout the whole three years are courses in mechanical drawing and practical mathematics.

In connection with the instruction in practical and applied science, it is important to note that the equipment of the school includes a specially prepared engine laboratory equipped with experimental engines, oil and fuel testing apparatus, cooling plant, etc. Each apprentice devotes the whole of one term—two hours' weekly science instruction—to a course of experimental testing in this room.

In addition there are two materials' laboratories well equipped with apparatus for tensile, compressive and torsional tests on wires, timbers and various metals. Impact and hardness tests are included together with metallurgical apparatus for the heat treatment of aircraft materials.

These are distinct from the ordinary science class-rooms which are equipped with the usual apparatus for the demonstration of fundamental principles.

An important feature of the school training is the course in general studies. This is intended, not alone, to be a mere relief from the more vocational aspects of the school training, but arises through the medium of a broad syllabus of historical studies, citizenship, literature and the evolution of the British Empire, in providing a personnel in the R.A.F. of thinking men who should be fully capable of taking their place as citizens of the Empire, both during and after their period of service.

School Staff

The instruction on the school side is administered by a body of educational officers who are all graduates of various universities and who are drawn entirely from the teaching and the engineering professions. They include a number of officers with actual flying experience, and with very few exceptions are all ex-officers of one or the other of the fighting services. The value of this last point lies in the fact that they are thus necessarily equipped with the peculiar requirements for liaison with both the technical officers in the shops from the training point of view, and the administrative officers of the barracks from the discipline and moral point of view.

I have dwelt at considerable length upon the educational side of this training because I, personally, am convinced that it is essential for the production of the particular type of mechanic required by the service.

There are many who consider that the majority of a mechanic's work is spent at the bench, and therefore that to give him extensive education is to waste time which might more profitably be spent in giving him more practice with his hands.

This may be so in some cases, but because the Royal Air Force is able to obtain suitable personnel at the outset by means of the competitive examination, rates of pay, conditions of service, etc., the proportion of those cases who do not obtain the full benefit from this side of their training is very small. A trained

mind is essential where every mechanic is liable to be transferred to a different type of engine or aeroplane at short notice, and may frequently be called upon to do his work in isolated places with makeshift tools.

Minor Trades

There are in the Royal Air Force aircraft apprentices who are being trained in the trades of turner, sheet metal worker, motor body builder, wireless operators, etc. The numbers so trained involved are very small compared with the trades of fitter aero engine or carpenter rigger.

A syllabus is arranged for each trade so as to include all the possible types of work likely to be met with in that trade. School syllabuses prepared to show the particular application of science and mathematics to the work in hand are followed step by step with the lads' work in shops.

I have here specimens of the exercises and types of work carried out which will show to those interested the range covered in these trades.

Final Examination

At the conclusion of the three years' course of training the apprentices are graded by combining the marks awarded locally for technical and school subjects, and for general efficiency, with the examination marks allotted by an independent board of technical officers; according to the grading so obtained the apprenticeship ends, and the boy passes-out into the service as an airman of a certain rank.

Although this period of instruction is now at an end, the ex-apprentice still lacks one most important factor. I mean experience, and this can only be obtained under actually practical conditions and by coming up against the particular difficulties and conundrums which he will have to cope with while in the Royal Air Force.

With this point of view the lad is not considered to be a fully-qualified mechanic until he has served one year in a service unit, where he is expected to acquire that experience which may enable him to apply what he was taught at the school of technical training to the best effect.

Inspections

Two invitation inspections have so far been carried out by a panel of inspectors from the Technological Department of the Board of Education. The first was at Cranwell, and the second, more recently, at Halton, and the inspectors have recorded their ardent approval of the progress and the value of this scheme of training. These reports, which are presumably public property, may be obtained through the medium of the Stationery Office.

A further indication of both the standard of training and of the extent to which it is receiving professional recognition is evidenced by the recent decision of the Institute of Mechanical Engineers to recognise the results of the final passing-out examination above the standard of 60 per cent. of the school subjects and 80 per cent. of the shop subjects as automatically qualifying for recognition for the studentship of the Institution without further examination. It is to be hoped that this recognition will before long be extended by other professional bodies, including, may I add, the studentship of the Royal Aeronautical Society itself.

Drill, Marching, etc.

I should like to say something on the subject of discipline, drill, marching, etc. There has been current an idea that an apprentice in the service spends a great deal of his time learning drill. This is a fallacy. The fact of this high standard being maintained is due to strict discipline and control being exercised

during the short but very frequent periods each day when he parades and marches to and from barracks, workshops and school. Apart from those periods the only working hours in which he receives specific instruction in these subjects is on Saturday mornings and at the conclusion of school periods.

In conclusion I should like to lay the following points before you :—

1. The system of training at Halton is on a very large scale, and it has not been in force for very long.
2. It is in no way tightly bound down; alterations in the syllabuses are being made every year, as experience shows up the weak points.
3. The qualities which it is sought to inculcate are :—
   Confidence in his knowledge and ability.
   Reliability.
   Accuracy in the use of tools.
   Reasoning power and initiative.

Civilian Apprenticeship

The principles by which an apprentice learns his trade at a commercial works is that he is set to work by a skilled tradesman, and under the control of a foreman. He acquires knowledge and skill by imitation and practice, and after a period varying from three months to a year and a half he is moved to learn the work of another department.

All work done is usually on production jobs, and consequently interest and the desire to learn and so work more quickly and efficiently stimulated.

The boy passes through various departments of the works, a note of his progress and tendencies being logged at each move.

In many cases at least three years' attendance at the evening classes of technical schools and colleges is a rule of the apprenticeship. This attendance consists of 2 to 2½ hours' class study three evenings a week, carried out after working hours during the winter sessions. A choice of various subjects of study may be made.

The boy's progress in these studies is noted, and certificates obtained, etc., are noted with the record of his practical work.

At the conclusion of the term of apprenticeship it is possible to judge from the five-year record in which particular direction the talents of an individual lie. One may excel at bench work and be quite unable to reach more than a very elementary standard in the schools. Another may achieve only very indifferent results with file or scraper, and yet be very good indeed at assembly or timing or trueing. Yet another may qualify highly in the technical college and find his sphere in the drawing office or design room.

In any case, when receiving his lines at the end of his apprenticeship, the boy has proved in which particular direction his best chance of success lies. Whether he remains with the firm, or moves on elsewhere, he will be able to fill the position of a fully-qualified mechanic.

The modern tendency is to look after the welfare of apprentices very much more carefully than was the practice in earlier days. Canteens, reading rooms, recreation grounds, organised sports and games and facilities for private study and research are only a few of the arrangements now provided by a firm for the benefit of their apprentices.

There are many more points upon which I could expand, such as :—
Size and positioning of the shops and aerodrome at Halton.
Games, organised and voluntary.
Leave. (1/- per day. 3/-, and retain 4/- until leave.)
Compulsion to serve only until the age of thirty, with the possibility of applying for re-engagement to complete 24 years' service for pension.

As I stated at the beginning of this paper, I very much regret that I am unable to place the system of civilian training before you with the same amount of detail as the service training which is being carried out at Halton.

I think a comparison would elucidate many points which would be of value; but as my experience is limited to short visits to only a few firms, I am quite unable on the present occasion to offer you that comparison.

Discussion

Colonel Sempill: It is easy to exaggerate and to say that this, that, or the other lecture is the most important of the Session, but I do feel very strongly that the paper we have just listened to deserves to be placed in the front rank. The work that Wing Commander Breese is doing is of an importance for the future of the Royal Air Force that can hardly be exaggerated. If the present system is all that it should be then there need be no cause for anxiety for the future. If anything appears to be lacking in certain respects, the system is capable of alteration with a view to its improvement and such alteration should be carried out at the earliest moment. The Royal Air Force depends almost entirely on the technical organisation as a whole and the technical personnel who have to make the system work.

I had hoped that Air Vice-Marshal Sir Philip Game, who is responsible for all these questions, could spare time to come here this evening and open the discussion or, failing this, to send a member of his department. This has not been possible and it is much to be regretted, as an official pronouncement on this question might do a great deal of good and would answer many of the unjust criticisms advanced in certain sections of the Press against the administration of the R.A.F. I suppose, however, that we shall not be far wrong if we take it that the system of training described to us by Wing Commander Breese accurately represents the policy of the Air Council. Had it been possible it would have been illuminating to have heard the views of someone, say, from the Engineer Chief's Department of the Admiralty on the R.A.F. system viewed from the standpoint of the present day system of training for the Navy.

Group Captain R. Peel Ross: I was not prepared to say anything on this paper except that I had one cartridge in my gun which I have now extracted. That is that in his paper the lecturer referred to wireless as one of the minor trades, but he explained when he read this, that he spoke of it as minor trades. We are rather proud of it as a trade at Flowerdown, where the training is very much on the same principles as at Halton. There is only one difference that may be interesting, and that is that our training in the trades of wireless operator, wireless mechanic and electrician runs concurrently through the shops and educational side. They don't go from section to section, but run concurrently the whole way through the three years. We have 300 aircraft apprentices and pass out 100 a year.

There was one thing that I was very glad indeed to hear. Wing Commander Breese mentioned that we feel very much indeed that it would be a great thing if the squadrons would realise more than they do that when a boy passes out he is not a finished article, but has just finished his apprenticeship. No boy can possibly be relied upon until he has done 12 hours' air work. When he leaves Flowerdown he has had, with luck, 1½ hours and can certainly not be relied on as a first operator. I am very glad to see that the author agrees with that.

With regard to hours of instruction, I believe the author mentioned they were four in the morning and four and a half in the afternoon. Might I ask what are the periods they are divided into?

Wing Commander BREESE: The period varies in the school classes and shops. The school morning period is from 9—12 in hourly periods. Before that an hour's drilling and marching is done. The shop morning period is 8—12, and that is one steady undivided period. The afternoons are arranged in the same way. Shops, 1.30—5 undivided; school, 1.30—3.30 in hourly periods. At the conclusion of that, games.

Group Captain R. PEEL ROSS: That is interesting in comparison with the electrical and wireless trades where they have periods of an hour each of whatever study they are at, and at the end of each hour there is a general circulation round. Each follows concurrently so that the apprentice does not become confused with the different sections of the particular trade, because there are so many. It is a difficult trade because you cannot see what a boy is doing except from his note books. I wish we could turn out things such as we have been shown. The Flowerdown boys *are* given a course in the use of tools. Apart from the differences I have mentioned, the general policy is exactly the same for training, games and so on.

Wing Commander T. R. CAVE-BROWNE-CAVE: It seems to me that it is particularly fortunate that this Society, which is apt to become a little absorbed in the severely material side, should have this paper presented to us. We are supposed to look after the application of the science of aeronautics. The personnel side is very important. It is very interesting to see how the factors of responsiveness and quickness are studied in the training of boy mechanics at Halton.

Lieutenant-Colonel W. LOCKWOOD MARSH: The Society are very much to be congratulated on having had this paper because its subject is, as the Chairman has said, the pivot—or as I should prefer to put it, one of the two pivots—on which the organisation of the Air Force and its efficiency turn.

There is one thing I should like to say at the outset. I do not think the lecturer need fear that anyone who has paid a visit to Halton, or who has made any study of the literature issued by the Air Ministry regarding the courses of training there, could for a moment maintain now, whatever may have been the case at one time, that too much attention is paid to teaching boys drill. It is perfectly obvious that the technical training given at Halton is extraordinarily efficient. It has always surprised me very much, looking at it from the parents' and boys' point of view, that the Air Force do not get more applications, compared with the number of vacancies that there are at Halton, than they do. I should have thought that they would get six or seven times the number of applicants than there are vacancies, because it offers to parents an extraordinarily fine opportunity for settling their boys in fixed occupation without fear of strikes or unemployment for a steady period of 15 years, at the end of which they can at the age of 30 leave the service thoroughly trained for good positions in civil life, or remain on in the service for a further period if they desire.

An important point is the attitude of the Trades Unions to the Air Force apprenticeship system. Do the Trades Unions receive men who come out after 12 years with the colours? This seems to me a vital point by which the whole scheme may have to stand or fall, and I should like to know whether the Trade Unions have agreed to recognise the course at Halton as constituting an apprenticeship.

Another thing that has much struck me is the stress which the author places on the importance given to the general education of the boys, which I think is extraordinarily important. I had not noticed this on reading the paper beforehand, but on hearing it read just now, I remembered that I happened to have in my pocket a cutting which bears on this point. It is from a book called *Romance and Reality*, by Herbert Read, and the quotation runs: "It has been a common saying, since Pope first said it, that a little knowledge is a dangerous

thing. But far more dangerous is the knowledge which, though not little, is limited."

I think it is a very great advantage of the course at Halton that the boys are not only trained thoroughly in engineering, but are educated as well. The value of this general education is shown by the fact that 12 boys annually can go on from Halton to Cranwell and be trained as officer cadets, and it has been found by experience that they do extremely well. I believe that the Sword of Honour at Cranwell was this year awarded to an ex-apprentice coming from Halton, while I believe that last year two Halton boys passed out top from Cranwell, which is, I think, great testimony to the efficacy of the training at Halton.

I said that Halton is, in my opinion, one of the two pivots of Air Force organisation—unfortunately the other is completely lacking. I think it is a great pity that this training stops at mechanics. The great need in the Air Force is an engineering branch for officers. The ordinary officer on the general list in the Air Force has on entry one, or at most two, years at Cranwell, where he receives elementary instruction in, among other subjects, engineering and aeronautical science, and then goes to a squadron. I think I am right in saying that none of them gets any further training in the technique of aeroplanes. About 20 to 30 a year go to Farnborough and have a 12 months' course in engines, and 12 of these go on to Cambridge for a theoretical education—compressing the three-year mechanical science course into two years—but they have no further practical training, which I consider a grave omission. The King's Regulations for the R.A.F. lay down that the officer commanding a squadron shall appoint a "properly qualified officer" in charge of the workshops. It has been a laborious work to find out what, if any, officers are properly qualified engineering officers, because, although officers who have taken this engineering course have an "E" after their names, this is only put against their names in the Seniority List and not in the Squadron List. About a year ago I tried to find out how many of these engineer officers were at the squadrons. It took me about four days to go through the whole of the two lists—the Seniority List and the Squadron List—and pick out the "E" officers at squadrons. I found that out of 45 squadrons only eight commanding officers were in a position to put in charge of their workshops officers with any qualification recognised by the Air Force list, and of those eight, three would have had to appoint themselves. There should be a separate engineering branch—as there are already separate medical, stores and accountancy branches—from which engineer officers would be appointed to units to have charge of, and be responsible for the efficiency of, all technical equipment. This would be merely reverting to the old systems in vogue in the old days in both the R.N.A.S. and R.F.C.

Colonel CURTIS: To one like myself, who has been associated with this scheme of training from the outset, the whole of Wing Commander Breese's paper bristles with points of interest. I want to-night, however, to say only a few words on certain wider issues. In recent years there have been great developments in the production of new materials for the engineering industry, and engineers have recognised the necessity of changing their methods and of re-training their personnel to deal with that material. I do not think it is very generally recognised that our teachers and our educational authorities have been almost as busy as our chemists, and that very considerable changes are taking place in the human material available for apprenticeship training. It is a little curious, I think, that a subject which is so important from the point of view of the efficiency of the engineering industry should appear so seldom in the proceedings of the professional institutions, and I think all those who are specially interested in this subject owe a debt of gratitude to the Royal Aeronautical Society for including this paper in their programme. I only hope that other

professional institutions may follow suit and include in their programmes similar papers on what has been done and learnt in this direction in recent years.

If we were discussing this evening the production of any aeroplane part or machine detail, I think we should find pretty general agreement on the material to be used and on the tests to which that material should be exposed. You will not find anything like the same agreement in regard to the selection of boys for apprenticeship training. I remember only too well, in 1919, when the question of the manning of the new Air Force was under consideration how forcibly it was impressed on my mind that there existed a school of thought which held that education was not of use to the practical man, and which even went further than that, and rather held that it was a disadvantage. It took the view that educational ability and mechanical aptitude were natural opposites, the presence of one indicating the absence of the other. That impression, I hope the experience we have gained at Halton in the last six years, will have served largely to dissipate. On that question I should like to put forward a definite theory. It is this, that in general a boy's educational standard affords a measure of the rate at which he can absorb technical training. I want to draw particular attention to the word *rate*. The theory does not assume that the better educated boy would necessarily make a better craftsman in the end, but only that the better his education the shorter his training need be. That is the theory which lies behind the present system of training apprentices at Halton and that is why the period is three years instead of five or seven. The system of training there turns largely on the fact that the scheme insists on a high standard of education at entry.

Going back in my mind to 1904, when the Admiralty scheme for the training of artificer apprentices was introduced, my recollection is that there was a very small proportion of boys with secondary school education available. At Halton roughly 70 per cent. are from the secondary and technical schools, and that affects the whole question of their training. Just as the new material available for engineering has necessitated a complete change of workshop practice and the re-training of the personnel, so I believe, this new material available for apprenticeship calls for a complete reorganisation for the methods of training and a re-education of the personnel engaged on instruction.

I think the time has come for a pooling of the knowledge of this and experience gained during recent years.

Two other points. A high standard of education at entry and the continuance of that education through the whole period of apprenticeship training is practically certain to produce as a by-product a number of men of very high ability. That has been shown very well by the Admiralty Dockyard scheme, which has produced some of our greatest naval engineers and constructors. I think Halton shows promise of following in that line, and one of the questions to be faced in the near future is what is the best use to make of this exceptional product? The other point is this. We hear a great deal to-day about the need of peace in industry. I think that question of unrest often turns more on general boredom than on discontent with the actual conditions in the industry. Widen a man's interests and outlook and boredom disappears. That is what lies behind the attempt we are making at Halton and at Flowerdown to give a wide general education, quite apart from the needs of the technical side. The education which we are giving, which takes a quarter of the time available for "school," is very definitely not of the school type. We are endeavouring to interest the boys in such subjects as that of how our present civilisation has come about, in questions of the day, in questions of economics, general reading, and in anything which deepens interest and will in future help to prevent the growth of that feeling of monotony and general dissatisfaction with life, which is one of the main causes of unrest.

Colonel SEMPILL: I have one or two questions to ask the lecturer before he replies to the discussion. I should like to know as to what percentage of Halton trained mechanics are now serving in the R.A.F. It would seem to me that two classes of mechanics are wanted—those competent to do what may be termed running repairs and those competent to undertake the highly skilled work, such as the complete overhauling of engines and major repairs of a like nature. The present system at Halton does not seem to fill either of these requirements and I am inclined to think that too much stress is being laid on general education. No one would suggest going to the other extreme, but at present I do feel there is cause for reconsidering the amount of time spent on education. The personnel that the system aims at turning out will have the duty of keeping in running order the maximum possible number of aeroplanes, and I think this point should be kept more closely in view.

With regard to the question of the apprentices becoming bored with their work, I should have thought that the repairing of aircraft engines was in itself sufficiently interesting to avoid this, but of course to attain this result it is necessary that they should be doing some productive work that is to be of value.

Another disadvantage that will probably arise as a result of the great importance paid to education is that the system would appear to be more suitable to the production of officers than air mechanics. This fact in itself is liable to give rise to a good deal of dissatisfaction unless promotion from the ranks is higher than now appears to be the case.

It would be interesting to know as to how much time is actually spent on drill.

Regarding the work of stripping and erecting engines, I should have liked to have felt that this was being done in most cases with up-to-date engines that would run. The paper gives the impression that out-of-date engines, which probably would not run at all, are kept for this purpose. This, surely, is a relic, or ought to be, of the days before the war when there were no engines available for such purposes because there were not any, or of during the war when all engines of any modern type were required for active service.

Touching on the question of working on scrap engine parts, it seems quite wrong and certainly not calculated to inculcate the best spirit in the apprentices. Surely it should be possible to so arrange matters that productive work of some kind or another can be undertaken. This course is followed in the Navy and we find that boys under training are employed doing actual useful work, of course being carefully looked after by the instructors. Many of the samples of work of all kinds brought here this evening by Wing Commander Breese show what a high standard is adopted. It would appear to me quite wrong that practically all these articles are of no use whatever. This is a state of affairs which required to be remedied.

Returning again for a moment to the system of training for the Navy and the R.A.F., it seems that the amount of time spent by the latter on practical work is not sufficient.

REPLY

Wing Commander BREESE, in replying to the discussion: I should like first of all to offer apologies to Group Captain Peel Ross for having included wireless operators under the minor trades. I should like to make it quite clear that all trades classified as Group I. in the R.A.F. are considered to be of equal importance. I have used the word "minor" solely from point of numbers.

Group Captain Peel Ross has remarked upon a very important point—experience. It is well nigh impossible, however hard you try to work it out, to give boys sufficient experience to enable them to be looked upon as the

finished article when they leave Halton. The ex-apprentice will inevitably meet, and have to deal with, many small yet difficult points which are bound to be outside his training experience. The practical experience necessary to cope with these must be acquired in the units where they arise. It is for this reason that the ex-apprentices, although ranked as "Airmen," are not considered fully trained until 12 months after they have joined a squadron.

Group Captain Peel Ross mentioned the specimens of handiwork which I have shown. I should like to emphasise that the skill exemplified by these test jobs represents only a small proportion of the work carried out during an apprentice's training.

Colonel Marsh remarked on the number of applicants. I entirely agree with him. I cannot understand why even more applicants than the present number are not received. We are asking for 500 every six months, and for that number we get approximately 700 applicants. These have to pass the competitive examination, and afterwards we eliminate down to the required 500. Of this 500, 50 go to Flowerdown and the remainder to Halton. Personally, I have spoken to many officers and parents on the subject and, though I may be biased, I believe it to be one of the finest opportunities for a boy that I can conceive. He has only to compete successfully in an examination, which, though stiff, is not really difficult. He then receives pay during the whole of his apprenticeship; he is given leave, with pay, up to six weeks each year, and is fed and housed under exemplary conditions. At 18 he passes out into the service with pay from 3s. 6d. to 7s. 6d. a day and everything found. He need only serve until he is 30, when he can leave and go to good civilian work if he so wishes.

The next question raised by Colonel Marsh was the attitude of the Trade Unions. I am very sorry that I cannot tell you what this is. It is a common-sense point which should have been faced, but I cannot say if it has. Colonel Sempill said he understood that the Trades Unions would *not* accept these boys. I do not know where that information was obtained. One point is, that no boys who have been trained under this system have as yet completed their ten years, and will not have done so until six or seven years have passed, so that the question will not arise for some time. However, it should have been foreseen. When the Council of the S.B.A.C. came down to Halton, among other things put up to them was the problem of the boy who completes his course of training, passes out, and for some reason, medical or otherwise, is not allowed to go into the service. The S.B.A.C. agreed that if we sent these boys to them —as the cases arose—they would find jobs for them. That has been done and these boys are now in the employ of the firms of various members of that Council.

Colonel Marsh told us of his difficulties in finding out who were trained as engineering officers. Since November these officers' names have been marked by a small (e) in the Air Force List issued by the Air Ministry.

Colonel Curtis made a general statement with which I am in entire agreement.

Colonel Sempill spoke on the question of the continuance of the syllabus of training. I intended to stress one point more than I actually did, and that is that the scheme at Halton is extremely adaptable. Just as an example, I may say that when we found out that a certain piece of chipping and filing took too much of a boy's time, we reduced the size of the piece. Six months ago we decided that it was still too much, and now the boy machines three sides of it. It is just a question of modification of the syllabus. The syllabus can be, and is modified, as a result of experience when any point crops up either in the shops or in the school, or as a result of reports from squadrons. The report is looked into, and if found to be sound, the syllabus is altered accordingly. There is no fixed red tape about the system at Halton. A comparatively free hand is

allowed; the reports are dealt with as they come in and the syllabus amended as required.

As to the percentage of Halton trained mechanics in the service, I must confess I do not at the moment remember the total number of mechanics in the R.A.F. If we admit it to be 30,000 then the present proportion of Halton trained mechanics will be about 2,000 to 2,400 out of 30,000, that is 6½ per cent. It must be remembered that every year 1,000 boys go into the service, and a considerable number of men go out, but no boys go out.

The question of having two classes of mechanics was raised. That is a point upon which there has been much discussion. The point is that there is work for two classes of mechanics; one skilled enough to do flight work, such as the tuning and maintenance of aircraft and engines, and the other sufficiently highly skilled to cope with the actual repairs of machines and engines. I think the key to the question lies in the necessity for the provision for expansion. If provision was only made for highly skilled mechanics, sufficient to cope with repair work in peace time, then if the necessity for expansion arose, there would be great difficulty in adequately meeting the emergency. Under the present conditions we are training all mechanics upon the more highly skilled scale. One great difficulty is that when they go out to units they will not all have work up to their standard of skill.

The matter of varying the work has been mentioned. We have found that, with the boys who are very young, when they are set to work at chipping and filing it is not similar to the same process as carried out in civilian work. It is more continuous. At Halton, in the afternoons, they have four and a half hours of one particular job and nothing else. It tends to be monotonous. We have found that that monotony would probably lose us a considerable number of boys at the end of the first year, unless we took steps to prevent it.

The number of hours spent in drill each week is seven. As stated in the paper, the only working hours spent on drill are Saturday mornings from 8 to 12. During that time they have clothing parades, barrack-room routine and so on, in addition to drill on the square.

Stripping and assembling of engines. It is very difficult to obtain modern types, principally for reasons of economy, but there are now at Halton a considerable number (some 80 odd) of modern types of engines, the Lion, Condor and Jupiter, etc., and 14 modern aircraft. Perhaps I was not clear in describing how they strip and assemble these engines. In the old days one took an engine down and put it together again, and if one or two parts were missing it did not matter very much. At Halton it is quite different. The engine shop is divided into bays about six yards square, with benches on three sides, in the middle being two engines of a type on stands and a blackboard. Opposite each bay is a fuselage suitable for the particular type of engine. The apprentices in classes of ten to a bay, strip the two engines, learn by sight, handling and rough sketching, the general details and arrangements of the engine. They then assemble it, erect it, and instal it in the fuselage; make all necessary connections, take it outside the shop and run it. It is then brought in, removed from the fuselage and replaced on the stand in the bay ready for the next class. An important point is that 75 per cent. of these engines are capable of and actually do run. In the course of next year it is hoped that all will be made runable.

The principal difficulty connected with the use of scrap engine parts is the question of numbers. At present work is being done upon old engine headers for example, cut up into two or three pieces, so that each boy may have some practice in the process. It would not, I think, be practicable to obtain sufficient parts, non-scrap, for each of the 900 odd boys to work on.

The question of produce is an extremely difficult one for us. To my mind

it is one of the greatest factors of civilian training that the boys make things which are of real use. With us they are seldom so. Difficulties would certainly be raised if, with service labour, we constructed articles and put them up for sale outside. It is very difficult to find out what particular articles we could make which would be suitable for service requirements. Offers of jobs for construction are welcomed, and recently 1,200 modification parts were turned out. We are very anxious indeed to obtain production jobs, but have not yet found many of suitable nature and in sufficient numbers to suit the training syllabus.

I think that Colonel Sempill stated that he considered the training of three years too short. One of the reasons for this period is economy. It is a very expensive training indeed, and if only one more year were added it would increase the cost per mechanic, which is already very high, by one third. We should welcome the idea of a longer course, but that is a matter of Air Ministry policy.

Concerning the relation of the officer to the mechanic. The point as I see it, is that you won't make the officer any better by making the mechanic worse. If the officer is good he will look after his own machine and see that all is right; if he is slack he will come down to the tarmac at the last minute, and if the mechanic says it is O.K. he will hop in and go off; you will not, however, tend to improve that type of officer by having a less capable type of mechanic.

I agree with what was said regarding the desirability for the provision of a technical officers' branch. Provision for this will probably be met in part by Halton trained cadets. These would provide a small but steady influx of technically trained officers for the Air Force, because they will have had three years sound technical training at Halton as well as a subsequent two years officers' training at Cranwell.

THE ARTICULATED CONNECTING ROD—AN ALTERNATIVE METHOD FOR FINDING ACCELERATIONS

BY W. S. FARREN.

In Mr. Fearn's article on this subject in the February number of the Journal, in which a solution is given in the form of a Fourier series, a reference is made to the unsatisfactory results of an attempt to use double differentiation of the displacement curve. It is generally recognised that such a process is fundamentally inaccurate, and analytical methods, either exact or approximate, are usually given in books dealing with mechanisms. For mechanisms of the piston-connecting rod type, in which the higher harmonics of the motion of the driven member diminish very rapidly, two harmonics in all generally give all the necessary accuracy, both for displacement and acceleration. Mr. Fearn's solution is of this type, though he includes a fourth harmonic (see *e.g.*, the expression for ρ at the top of page 138).

There is an alternative graphical solution which gives velocities and accelerations with the same accuracy as displacements. It is applicable to any mechanism in one plane, though in certain special cases a modification is necessary. It is based on the solution by vector diagrams of the typical plane mechanism, the "four-bar chain." The author has failed to find any reference to it in books on mechanism, though it is undoubtedly well known academically. It deserves to be better known by those who are concerned with the accelerations of mechanisms, as it presents no difficulties in practice, even in very complicated examples, and for certain important types of mechanism it is much simpler than any other method.

For any link work, such as the mechanism under discussion, the solution is absolutely straightforward, if the appropriate vector diagrams (of velocity and acceleration) are drawn, of course for a number of positions of the driving crank. But much of this labour may be avoided by taking advantage of the relations between these diagrams and the mechanism itself, the construction being made on the drawing of the mechanism. No calculations are then necessary, except for "dead centre" positions, and lines in the velocity and acceleration constructions then represent their respective quantities to the scale to which the crank represents, respectively, the velocity (ωR) and acceleration ($\omega^2 R$) of the crank pin.

For the simple piston-connecting rod combination this corresponds to the constructions known as Klein's or Mohr's, which are generally given in books on reciprocating engines.

The constructions for one position of the articulated rod mechanism are shown in Figs. 1, 2 and 3, which are described in detail below. From the diagrams there shown (Figs. 2 and 3 are really explanatory and are contained in Fig. 1) may be obtained at once the angular velocity and acceleration of all the members of the mechanism, or the linear velocity and acceleration of any point fixed relative to any member.

The same principle may be used to solve the analogous problem of a cam and follower. For so far as displacements, velocities and accelerations are concerned, the surfaces in contact may be replaced by their circles of curvature at the point of contact, and it is evident that the line joining the centres of these circles corresponds to the "connecting rod" of a "four-bar chain." The "equivalent four-bar chain" changes from moment to moment, but it may readily be shown that the replacement is valid. The author has again been unable to find any reference to this method in any modern book. It is mentioned by Willis,* who suggests that it was known to Euler. Willis appears not to have been interested in the problem of determining the accelerations of a given

* *Principles of Mechanism*, 2nd Edition, 1870, p. 21.

mechanism, probably owing to pre-occupation with the special case of a mechanism with no accelerations—the gear wheel.

For most cam mechanisms the motion is so different from a sine curve that a Fourier series presents few advantages, being hardly less troublesome than an exact analytical solution. Both are very much more laborious than the graphical method here described.

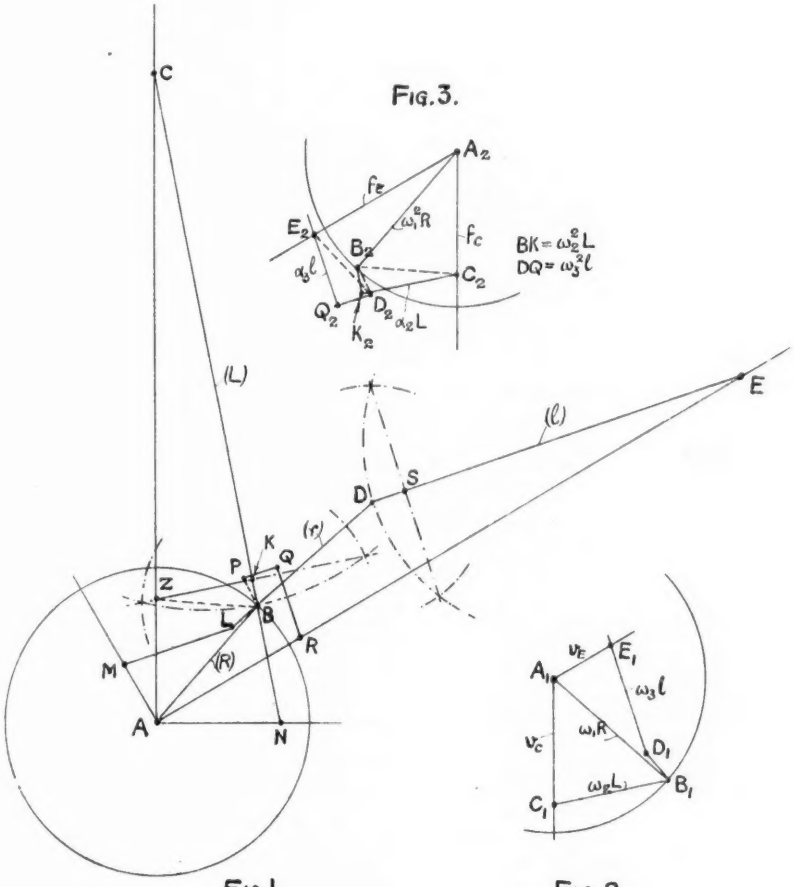


FIG. 1.

FIG. 3.

FIG. 2.

There is one feature of the treatment by Fourier series which is perhaps worth noting. As Mr. Fearn shows on p. 138, the approximation to the displacement is extremely close—in the example he gives the greatest error is about 1/2000 of the crank radius. But the approximation to the acceleration is not quite so close, since the higher harmonics are magnified, the nth in proportion to n^2, when differentiated twice. Thus, taking the essential figures of his example,

$$\rho = 8.17 + 1.19 \cos\theta - 0.12 \cos 2\theta - 0.001 \cos 4\theta + 2.06 \sin\theta + 0.09 \sin 2\theta$$

and therefore

$$\rho/\omega^2 = -1.19 \cos\theta + 0.48 \cos 2\theta + 0.016 \cos 4\theta - 2.06 \sin\theta - 0.36 \sin 2\theta.$$

In a less regular motion the approximation might be comparatively poor. Thus in many cam mechanisms there is a sudden change of acceleration, from a positive to a negative value, and a Fourier series is bound to give trouble in such places. With linkworks, however, this does not arise in general, the displacement curve having no sudden change of curvature. The coefficients of the corresponding Fourier series then decrease ultimately like the numbers[†] 1, $1/2^4$, $1/3^4$, $1/4^4$, etc., so that the coefficients in the derived expression for the acceleration decrease ultimately as 1, $1/2^2$, $1/3^2$, $1/4^2$, etc. This is illustrated by the above example.

Description of Figs. 1, 2 *and* 3

AB is the main crank, CBD the master rod, DE the auxiliary rod. $AB=R$, $BC=L$, $CD=r$, $DE=l$.

ω_1, ω_2, ω_3 denote the angular velocities of AB, CBD and DE respectively.

α_2, α_3 denote the angular accelerations of CBD and DE respectively.

v_c, v_e and f_c, f_e denote the linear velocities and accelerations of C and E respectively.

Then in Fig. 2, the velocity diagram, $A_1B_1=\omega R$ is the velocity of the crank pin, B_1C_1 (perpendicular to BC in Fig. 1) represents the relative velocity of B and C and A_1C_1 (parallel to AC) represents the velocity of C. Thus $B_1C_1=\omega_2 L$ and $A_1C_1=v_c$.

If $C_1B_1D_1$ be made similar to CBD, then A_1D_1 is the velocity of D. Draw D_1E_1 perpendicular to DE and A_1E_1 parallel to AE. Then $D_1E_1=\omega_3 l$ and $A_1E_1=v_e$.

$A_1B_1C_1D_1E_1$ is the velocity image of $ABCDE$. If the scale chosen be such that $A_1B_1=AB$, then it may clearly be drawn on Fig. 1, *provided it is turned through* 90°. It is there shown by the points $ABNLM$. AN is perpendicular to CA, AM to DE.

Fig. 3 shows the corresponding acceleration diagram. $A_2B_2=\omega_1^2 R$ parallel to AB, to which it is made equal. $B_2K_2=\omega_2^2 L$ is the relative acceleration of C to B in the direction CB. In Fig. 3 B_2K_2 may be regarded as found by calculation using the value of ω_2 found from Fig. 2. As is shown below, it can conveniently be found by a graphical construction. Draw K_2C_2 perpendicular to BC and A_2C_2 parallel to AC. Then $K_2C_2=\alpha_2 L$ and $A_2C_2=f_c$.

Make $C_2B_2D_2$ similar to CBD. Then A_2D_2 is the acceleration of D. Draw $D_2Q_2=\omega_3^2 l$ parallel to DE (ω_3 may be found from Fig. 2). Draw Q_2E_2 perpendicular to DE and A_2E_2 parallel to AE. Then $Q_2E_2=\alpha_3 l$ and $A_2E_2=f_E$, the acceleration of E.

$A_2B_2C_2D_2E_2$ is the acceleration image of $ABCDE$. As with the velocity diagram, Fig. 3 may be drawn on Fig. 1, *provided it is turned through* 180°. It is there shown by the points $ABZPR$. K and Q correspond to K_2 and Q_2.

The following construction for BK (or B_2K_2) is generally known as Klein's. Draw a circle on BC as diameter and a circle with centre B and radius BN. Their common chord cuts BC in K. This is the equivalent of finding K, so that $BK \cdot BC=BN^2$. To find PQ (or D_2Q_2) draw a circle on DE as diameter and a circle with centre D and radius LM. Their common chord cuts DE in S and $DS=PQ$. Again this is equivalent to $PQ \cdot DE=LM^2$.

Thus Figs. 2 and 3 are unnecessary and Fig. 1 represents the whole of the work required to find ω_2, ω_3, α_2, α_3, v_c, v_e, f_c and f_e, and incidentally the linear velocity and acceleration of any point rigidly connected to any of the members of the mechanism. It will be observed that no calculations are involved (of necessity, though in practice it may be preferred to find the points K and Q by a direct calculation). There is therefore an inherent improbability of an appreciable error passing unnoticed—a valuable feature of many graphical methods.

[†] See Lamb's *Dynamical Theory of Sound*, § 35.

BRANCH NOTICES

Yeovil Branch (Westland Aircraft Society)

(*Hon. Secretary*, Mr. V. S. Gaunt.)

The following is a summary of the activities of the branch during the last month:—

January 12th.—10th Lecture for Prospective Ground Engineers. Subject, "Salvage." Lecturer, W. G. Gibson, Esq., A.R.Ae.S.

January 19th.—11th Lecture for Prospective Ground Engineers. Subject, "Other Aircraft Timbers." Lecturer, T. Carey, Esq.

January 26th.—12th Lecture for Prospective Ground Engineers. Subject, "Glues." Lecturer, H. Burdett, Esq. (of the Improved Liquid Glues Co.).

January 28th.—5th General Interest Lecture. Subject, "Magnetos." Lecturer, A. P. Young, Esq., A.M.I.E.E. (of B.T.H.).

February 2nd.—13th Lecture for Prospective Ground Engineers. Subject, "Engine Installation Overhauls." Lecturer, H. E. Somers, Esq., A.I.D.

February 4th.—6th General Interest Lecture. Subject, "Air-Cooled Aero Engines." Lecturer, A. H. R. Fedden, Esq.

February 9th.—14th Lecture for Prospective Ground Engineers. Subject, "Aircraft Steels." Lecturer, J. Hopcraft, Esq. (Thos. Firth and Sons).

The following additions have been made to the Library:—"Bristol Jupiter VI. (Manual); "Bristol Jupiter VI." (description of methods of manufacture, reprinted from *Machinery*); "With Cobham to the Cape" (presented by W. G. Gibson, Esq.); "The Development of Stainless Steel" (presented by Messrs. Thos. Firth and Sons); "Handbook on all types of B.T.H. Magnetos" (presented by Messrs. British Thomson Houston Company).

AEROPLANE CONTROLS: FAULTS AND DIAGNOSIS

Paper read at the First Meeting for Prospective Ground Engineers, held at 7 p.m., at the Westland Aircraft Works, Yeovil, on 27th October, 1926.

BY W. G. GIBSON, A.R.AE.S.

(WORKS MANAGER, WESTLAND AIRCRAFT WORKS).

Before commencing this series of talks I wish to point out that they are an attempt to collect, on broad lines, information which is not always easily obtainable by the specialist—in other words, the man who is always engaged in making wing or rudder frames has not the opportunities for obtaining information regarding flying control adjustments. For this reason, and because it is regarded as more than desirable that aircraft constructors of all grades should be qualified ground engineers, the present series of talks has been arranged.

It is proposed to deal this evening with the functioning, maintenance and adjustment of flying controls.

Aeroplane controls are now standardised on all makes of machines both in England and abroad, so that the instinctive movements once learnt by the pilot on one type of machine may be applied to any other type of aeroplane. In the early days of flying this was not the case. For instance, on the baby "Wright" machines the elevator was operated by one lever working fore and aft, the aileron by another lever also working fore and aft and the rudder by a very short lever on top of the aileron lever. On the "Antoinette" monoplanes the elevators were worked by a wheel running fore and aft, the ailerons by another wheel also moving fore and aft, and the rudder by a rudder bar similar to that now in use on modern machines.

Undoubtedly the diversity in methods of control accounted for some of the accidents met with in the early days of flying, when pilots learnt to fly on one type of machine and attempted to fly another which required totally different control movements. The system of control now in use generally was first adopted by Robert Pelterie, who still holds patents for the use of the universally jointed control column, usually known as the "joy stick," and within a very short time it became practically the standard method of control.

The movements now standardised are as follows and give more or less instinctive control, just as riding any type of bicycle is instinctive. The rudder bar is always pushed forward on the side to which it is required to turn. That is to say, if the left foot is pushed forward, the trailing edge of the rudder should move over to the left also, giving the rudder movement required for a left hand turn. The rudder of an aeroplane is, in this respect, comparable to the rudder of a boat.

To climb the machine, the instinctive movement is to lean back, and the pilot therefore pulls the top of the control lever towards him. This results in an upward movement of the trailing edge of the elevator, lessening the angle of incidence of the tail plane which depresses the tail and gives the machine, as a whole, an increased angle of attack to the air.

To descend, the instinctive movement is to lean forward, and the pilot therefore pushes the top of the control lever forward, thus depressing the trailing edge of the elevators which increases the angle of incidence of the tail, increasing the lift on the tail and decreasing the angle of attack of the machine as a whole to the air.

To tilt the machine over to one side, the instinctive movement is to lean over to that side. Therefore, to depress the wing on one side, the pilot pushes the top of the control column over to that side, which has the effect of lifting the trailing edge of the ailerons on that side and depressing the trailing edge of the ailerons on the other side. The effect of this is to reduce the effective angle of incidence of the other wing which it is desired to drop, therefore reducing the lift on that side, and to increase the angle of incidence on the side which it is desired to raise.

Certain modern machines are now fitted—for reasons which will be explained later—with a differential motion to the ailerons. For small movements of the control column this gives the same result as already mentioned, but for extreme movements of the controls, a decrease of angle of incidence on the wing it is desired to drop is obtained without a corresponding increase on the wing which it is desired to raise.

It is extremely important to memorise these required movements, and very serious accidents are known to have been caused through faulty coupling of the control systems, resulting in opposite movements to those desired having been obtained.

The maintenance of flying control systems in general presents very little difficulty. The following points should periodically be attended to:—

Control Cables

Should be carefully watched for rust or wear on the cables, resulting in fraying. If either of these occurs the cables should be taken out and replaced.

All Pulleys

Should be carefully lubricated and cleaned to ensure that they do not jam up and cause friction and wear on the cables.

Fairleads

Should be kept clean and watched for wear. In this connection a worn fairlead is usually the sign that the cable requires attention. It is not nowadays the practice to grease or lubricate fairleads as it is found that "dry" cables have a longer life.

Bearing and Pin Joints

In the control system generally should be watched for signs of slackness, and if this occurs, oversize pins should be fitted or new bushes fitted, the latter being the better way of doing the job. In no case should pins be fitted more than 1/64in. oversize. If more than this is required it is evident that either the bushes or the members to which the pins are fitted require renewal.

Levers

Should be carefully watched for signs of strain, as it must be remembered that the levers of an aeroplane are as light as possible consistent with the loads they have to carry and that if they are accidentally bent, offset loads will be put on to them which they were not designed to carry and under which they may fail.

The Shafts

On the control system should be carefully watched to ensure that they are free of their bearings and that no distortion of the structure, which would pull the bearings out of line and consequently strain the control structure, can happen. An aeroplane structure is comparatively light and fragile and where the control shafts are attached to different points on the structure very slight distortion may result in binding of control shafts. Should this be apparent and not be due to distortion of the structure, it can usually be rectified by very thin packing of sheet metal to line up the bearings correctly.

Aeroplane cables may be spliced in two different ways, according to the types of cables used, but for the controls which are taken round pulleys or fairleads, an extra flexible steel cable should be used, spliced with a standard "tuck" splice round a brass or tinned steel thimble and properly bound with waxed thread. In certain cases cables are spliced for a particular purpose round circular metal thimbles, known as "dead eyes." Soldered splices are on no account permissible with an extra flexible steel cable, as it is not suitable for this type of splice and the flux used for soldering has a serious corrosive effect on the cable.

A number of present-day machines use chains and sprocket wheels in place of pulleys, and these require very careful attention with regard to freedom and inspection for wear.

The alignment and adjustment of guards on chain sprockets are of very great importance, as a chain which is jammed cannot be freed by the pilot, as is possible with a cable. If a replacement of chains is necessary, they should be obtained from an approved maker, and should be tested in accordance with the Air Ministry's requirements at that time. Opening out of chain links, etc.,

to attach end fittings or cables or wires should not be done without the maker's sanction and approval.

So much for the working and general maintenance of the control system. Now to consider the many adjustments which are necessary in practice.

To those faults reported by the pilot, a certain amount of thought has to be given before such faults may be corrected, as faults noticed by the pilot may have their origin in any of several different sources, and it is for the ground engineer to determine by intelligent observation which of the possible causes has given the trouble.

The most common fault reported by the pilot is to the effect that the machine is flying one wing down; in other words, that when the control column is released and the machine allowed to fly hands off, the machine immediately sinks on one side. This may be due to many different causes. It is even possible for another pilot to fly the same machine and to say that the machine is all right or even to say that the machine is flying with the other wing down, as most pilots habitually fly from one particular side of the machine, *i.e.*, they keep a look out over the left hand side of the machine, and thus continually leaning over bring the control column to that side.

Having satisfied oneself that the fault actually exists with the control column released, the machine should be examined with a view to seeing which is the fault which is causing this defect. It may be that the ailerons are so rigged that when they are in correct position the control column is not vertical. This can easily be seen by examination. Possibly the ailerons are rigged so that the top and bottom wing ailerons on one side or other do not line up with their respective trailing edges simultaneously. In this case the remedy is obvious.

It may be that one of the flying wires has slackened off, allowing deflection of the wings, giving an increased or decreased angle of incidence. Or, as is most usually the case, it is due either to bad rigging or, in the case of a machine which has already done a certain amount of flying, the rigging has settled down and requires a slight adjustment. It is possible, in a good many cases, to see immediately which wing requires attention by sighting machine from behind and seeing that the trailing edge of the wing is parallel with the leading edge. In other words, if either of the wings has a wash-in or wash-out it can be seen by the eye. It is obvious, of course, that the wing which is flying down will require an increased angle of incidence, and if this particular wing, or the wings on this side, show a wash-out the remedy is obvious.

The rigging should be adjusted to increase the incidence and reduce, or entirely do away with, the wash-out. It may be, of course, that both wings appear to have an uneven angle of incidence throughout their span. If this is so, and none of the foregoing defects can be found, the rigger must determine what steps he has to take. It should be taken as a general rule that it is better to decrease an angle of incidence than to increase it. An increased angle of incidence means that the machine may yaw or swing and may also decrease the speed.

If it is found that a wash-out or wash-in is required to the extent of more than 15 minutes, *i.e.*, $\frac{1}{4}°$, the machine should be levelled up and re-checked throughout, as the rigging is obviously in error somewhere.

The next common complaint in my experience made by pilots is that the aileron control is heavy. Here again the pilot's opinion must be received with due consideration as to whether he knows the machine, or the type, intimately. For instance, a pilot who is used to flying single-seaters would naturally consider that a D.H.9 was heavy on controls, although the D.H.9 which he had flown might be, in all respects, perfectly rigged. However, assuming that the pilot knows the type of machine and is of the opinion that its aileron control is heavy for its type, the following points can be investigated:—

The cables, rocking shafts, fairleads, pulleys, etc., should be examined for signs of seizing up or hard rubbing and any traces of these defects removed.

It may be found that the ailerons foul the spars of the wing at the attachment points and are setting up friction, in which case they should be removed and the fairings eased off to give clearance and re-covered. It can be assumed that the hinges are in line and have not been forced into position, as this would certainly tend to make the controls heavy.

The droop of the ailerons should be checked to ensure that it is not more than that laid down by the manufacturer, as an increase in droop is invariably accompanied by heavy aileron control. If this is found to be more than that laid down by the manufacturer, it should be reduced to not more and, if possible, rather less than the stated figure.

Some machines are fitted with control levers which allow of several different positions with the control wire attachments, thus varying the gearing between the pilot's control and the ailerons, and it is as well to see that the normal position has been used and that both sides of the control are coupled to the same points on the control lever, as this, if incorrectly done, will cause unevenness in the control, resulting in more effort being required for one side of the machine than the other.

It may also be found that although the droop is correct when measured, one or other of the ailerons is warped, causing an actual increase in the average amount of droop over the whole aileron. If this warp or twist cannot be rigged out without overstraining the wires, the ailerons should be taken off and trued up and then refitted.

It is important to see whilst examining pulleys that the wires line up with reasonable accuracy to the pulley grooves as, if not, a fair amount of friction may be set up by rubbing on the walls of the grooves instead of the bottom. Should this be found to be the case, the levers from which the wires run should be examined as they may be bent, and if this defect is not cured in time it may, later on, have a serious consequence. I have known a case where the control shaft passing underneath the pilot's seat was so close to the seat bearers that the pilot's weight deflected the seat bearers sufficiently to make them touch the shaft running underneath. This, of course, set up serious friction which made the controls appear to be very heavy.

If all the above points have been attended to and the machine is still reported to be heavy, the only thing which can be done to improve the controls is a variation of the droop, and the pilot should be asked to see whether the ailerons in flight line up truly with the trailing edge. If they do so, or if they still have a slight droop below the trailing edge, the droop on the ground may be slightly decreased so that, in flight, they fly not more than $\frac{1}{4}$in. above the main trailing edge. This may improve matters, but if not, the ailerons should be securely held whilst somebody applies a load on the joy-stick and the ground engineer goes round and examines every control point, fairlead, or lever to see that nothing is being deflected out of its proper position. Some of the older types of machines are serious offenders in this respect, and it is possible that pulley brackets, shaft bearings, etc., which are entirely satisfactory while the ailerons have no load on them, are sufficiently loose or worn to deflect from the proper positions and set up serious friction when the ailerons have a load on them in the air.

Sloppy controls are easily traced to their sources by carefully examining the control system. The chief causes are slack cables either in the control system or the balance wires, or slackness in the pins, bushes or bearings resulting in backlash in the controls. If none of these is apparent, it is as well to examine the fixing of the aileron levers to the aileron spars as these have been known to become slack owing to the shrinking of the woodwork which, of course,

cannot be seen from an external examination. The controls should not be so tightened up, to overcome slackness, sufficiently to make the wires extremely taut, as this will not only tend to make the control heavy, but in a good many cases will result in these wires taking actual flying strains which they are not designed to take (elevator controls, for example, may function as drag wires).

The pilot will occasionally report that the controls at certain speeds flutter. It is more likely to be the case with tail controls and can usually be traced to slack hinges or loose tailplane fixing points, including tailplane bracing wires or struts. The cure for this is obvious. With tailplane gear similar to the Bristol Fighter it is important that the control cables in this case are reasonably taut, as all flying loads on this particular type of tailplane control are transmitted through the wires and slack wires will easily set up flutter on the tailplane. It is important that if a serious case of flutter has been reported, and the reason discovered and put right, the part of the control system affected should be carefully examined. For instance, if the rudder has been reported as having a flutter at certain speeds and the cause has been found to be slack cables, which have been rectified, the examination should not stop there. The rudder bar, rudder lever, and the rudder bar pivotting points should also be examined as the application of the quickly reversing loads consequent on flutter may have loosened any of these parts.

The pilot may, but this is not a frequent occurrence, report that the machine is becoming abnormally tail heavy or nose heavy. The trim of the machine varies considerably with the speed, therefore it is as well to find out before taking any action whether this difference in the trim of the machine is apparent at the normal cruising speed, *i.e.*, the speed at which the machine is normally flown with the engine throttled back to reasonable revolutions. If the defect is apparent within the cruising speed range, investigation should be made to determine the reason. It may be that the machine had exhibited this characteristic when flying with greater or less than its normal ballast or passenger load. In such a case it would be as well to have the machine re-tested carrying its normal load. It may be, and I have known such a case actually happen, that several heavy spanners, etc., have been left on the tail end of the fuselage. If the cause appears to be more obscure, the tailplane should be checked to see that it is properly rigged and that neither the front nor the rear spars are strained out of level, giving increase or decrease in actual incidence. If this point is found correct, it is worth while running a line along the side of the fuselage to see that the fuselage has not distorted in its length and that the bracings inside are not sufficiently slack to allow of deflection in the air.

The more usual reasons for machines being tail heavy or nose heavy will probably be found to lie among one or other of the foregoing.

If the machine is reported as being generally sloppy, it should immediately be brought in and thoroughly checked over, both on control points, strut fixings, tension of wires and spar fixing points as otherwise the fault, wherever it is, will develop very rapidly if the consequence of sloppy rigging is allowed to go on. Whilst dealing with this it is as well to point out that the external drag bracing fitted between the leading edge of the wings and the front of the fuselage on some machines should not be over-tightened and should, in fact, be somewhat slacker than the remainder of the rigging wires, as the tightening up of those wires induces strains on the wing structure which it is not designed to take and may prevent the internal drag bracing of the wings taking their correct proportion of the drag loads, thereby throwing the whole of the drag loads on to the external bracing.

It is occasionally the case that the machine is reported to have a tendency to swing in one particular direction when taking off or possibly even in the air. This may be due to the design of the machine, as certain machines such as the

Avro S.E.5 and practically all machines with rotary engines have this tendency. If, however, the case is an isolated one, the reason can generally be found in the fin being out of vertical, either through being badly braced or the fuselage having been twisted, throwing the fin out of truth in relation to the main planes. Certain machines are fitted with elastic or spring devices to check this tendency to swing and to relieve the strain on the pilot in the air and the adjustments of these should be done with the greatest care. If the device is adjustable by the pilot it should be so adjusted on the ground in the off position that there is no load whatever on the spring, as when the engine is not running, or is throttled down considerably for descending, the tendency is not apparent and no initial load on the rudder is required.

One not very usual cause of a machine flying "one wing down" is the tailplane being out of line with the wings, *i.e.*, out of level from tip to tip. By putting the tail on a trestle and "sighting" from behind, this point may easily be checked. The tendency in such a case is always for the rear (the tail) plane to fly level.

The foregoing is a general statement of the usual reports received from pilots and will cover any, except the most abnormal trouble. I have only met one case which was not covered by the usual routine adjustments, and in this case the left hand bottom aileron had been fitted to the right hand top wing and it took three days to discover the reason for the erratic behaviour of the machine. The speaker was not the offending individual!

CONSTRUCTION AND ASSEMBLY OF FLOAT AND BOAT SEAPLANES

Paper read at the Sixth Meeting for Prospective Ground Engineers, held at 7.15 p.m., in the Mermaid Hotel, Yeovil, 1st December, 1926.

BY V. S. GAUNT, A.R.AE.S., A.M.I.AE.E.

(*a*) Float Seaplanes

Are aircraft which take off from and alight on water for which purpose they are mounted on float chassis in lieu of the usual wheeled undercarriage. The superstructure is generally similar to that of the normal land machine, but there are a few points of difference which are worthy of note, viz. :—

(1) Most float seaplanes are provided with slings for hoisting purposes.

(2) Many are fitted with wing tip floats which preserve lateral stability afloat.

(3) Most possess folding wings to enable them to be more easily stowed on board ship.

(4) The chassis is usually more robust than that of a similar size of land machine, because of the buffetting which seaplanes must withstand whilst afloat, and also because of the two point suspension necessary with floats.

There are four main types of float seaplane, viz. :—

(*a*) The normal tractor twin float type with a tail float and wing tip floats.

Type (*a*) is best illustrated by the "Short" 225 h.p. seaplanes, of which large quantities were built and used during the war.

(*b*) The twin float tractor type in which tail and/or wing tip floats are dispensed with, the main floats being of such a size and disposition as to preserve trim and stability.

Type (*b*) is a more modern development and the Fairey types are best known. Some of these, however, preserve the tail float. The Curtiss and Gloucester and Supermarine racing seaplanes are types which have neither tail floats nor wing tip floats, whilst Blackburns and Vickers have each produced training seaplanes of this type. More recently the D.H.50, used by Sir Alan Cobham, has been converted to a seaplane of this type and the "Moth" seaplane also relies on two long main floats only.

(*c*) The twin float pusher type.

Type (*c*) is rarely seen. The only machine of this type which I can recall is the Maurice Farman.

(*d*) The single float tractor type.

Type (*d*) is also rare, but the Glenn-Martin and Dayton Wright firms of U.S.A. have built this type of machine.

The seaplane with only two main floats may be considered as the most modern development. The advantages of this type are threefold.

(1) The tail unit has more clearance from the water.
(2) The fuselage is relieved of the stresses imparted by a tail float.
(3) The planes are relieved of all loads due to wing tip floats.

Float Design and Construction

There are two main types of float, viz.:—

(1) The pontoon or box type.
(2) The turtle back type.

The former has many variations, but all have a rectangular or pentagonal cross section, the deck being usually flat or nearly so. This type has a framework comprising four longerons and a keel or keels framed together by means of struts and bulkheads. The covering in the older types was of three-ply with the addition of aluminium on the under surface. Modern types have little or no three-ply but are planked, *i.e.* boat built. The longerons are usually made of either ash or rock elm, whilst struts and stiffeners may be of spruce. The planking itself is usually of cedar or mahogany. The outer surface of the float is often covered with painted fabric, whilst in the double skin type varnished fabric is laid between the skins. The keel is usually backed up by a keelson which extends from top to bottom and end to end of the float, so dividing it into two halves. Transverse watertight bulkheads are also fitted in order to divide the float into six or eight compartments.

The turtle back type is the more modern form. The distinctive feature is that the deck is of approximately semi-circular cross section. This tends to cleaner running as water is more easily shed.

In all types of float there is what is called "the step"; this being a break in continuity of the lower or planing surface so that the after portion is two or three inches higher than the fore body. This step serves to break down the suction of the water and so assists the "take-off." In the original "Short" type of float the heel of the float itself forms the step. The shape of seaplane floats has gradually been evolved as a result of model and full-scale tests, but there still remains a considerable diversity of forms. The total displacement of the floats may vary from $1\frac{3}{4}$ to $2\frac{3}{4}$ times the fully loaded weight of the seaplane. After deciding the form of the floats, models are made and tested in the William

Froude tank at the N.P.L. These tests show whether the floats run cleanly and the angles of trim at different taxi-ing speeds are observed.

The angle of the forward planing surface of the floats relative to the chord of the planes is of the utmost importance. With a long, stepped float the upward and backward slope of the planing surface abaft the step is also important, as this affects the angle to which the machine can be tilted for taking-off.

In taxi-ing, the seaplane rides gradually higher and higher in the water, due to the inclined planing surface until, just before the take-off speed is reached the machine is riding on the step about which it can be slightly "rocked" by means of the elevators and so "hoicked" off. In calm meather the modern seaplane can usually be unstuck without "hoicking." It will be realised that the position of the step is most important and that it must approximate to the C.G. (fore and aft). It will also be obvious that the step must be the strongest part of the float.

The floats are almost invariably mounted on two axles which are housed within steel fittings built into the floats either just below or on top of the deck. These axle fittings carry lugs for the attachment of chassis struts and wires.

Assembly

In erecting a float seaplane the fuselage must be set up and levelled on trestles at such a height as to allow the float chassis to be inserted together with the launching trolley (which is a wheeled sub-frame used for moving the machine about in the shed or on the slipway or beach). If the machine is an amphibian the wheels will most probably be housed within the floats, projecting some 6in. or so below the keel near the step. After assembling the floats to their axles the chassis structure is erected and lining up commenced. The important points to watch are:—

(1) The exact fore and aft position of the floats relative to the main plane spar joint fittings. This distance is usually dimensioned from spar centres to the centre of one of the axles.

(2) The angle of the floats relative to the datum line of the fuselage. The top of the float is usually straight for some portion of its length. If the floats are of the "box" type, levelling should be done from the edge of the deck, *i.e.*, over the top longerons. If of the "turtle deck" type the centre line is, of course, the best datum line. In both cases the levelling should be done from the portion of the float between front and rear axles as this is the strongest portion and will therefore be the most accurate.

(3) The setting of the floats truly parallel to each other and level athwartships. This is usually fixed automatically by the axle fittings.

Handling

There are certain precautions to be observed in supporting and handling floats. Whenever possible floats should be supported on their launching trolley, but if for any reason this is not available, trestles may be used with shaped cradles to fit the contour of the planing bottom. The main trestles should be placed at the main step as this is the strongest point.

Auxiliary trestles should be placed forward of this point and preferably immediately under the front axle centre line as there is sure to be a strong bulkhead there. In the case of long floats a trestle should also be placed under the heel, *i.e.*, the stern of the floats. Sometimes the float tapers aft to a vertical knife edge to blend into the water rudder which will be carried on and protected

by a "skeg," extending from the keel, with which the trestle should make contact.

Whilst floats are in storage or being erected it is advisable to lift the inspection covers, which are fitted in the deck to give access to each compartment, as this will ventilate them. Perforated gauze discs are useful to cover these openings in order to prevent nuts, bolts, etc., from dropping inside.

If the floats have been in store for some time the joints and planking should be examined to see whether undue shrinkage has taken place; if so, it may be advisable to cover with damp cloths or run water into each compartment. This can later be pumped out by means of a bilge pump or drained off via the drain plugs which are usually fitted to the lowest point of each compartment of modern floats.

The rear chassis struts sometimes embody shock absorbers. Other machines may have all struts rigid and embody the shock absorbers within the floats—the axle housings being anchored to the floats by rubber rings or shock absorber cord. Other seaplanes have no shock absorbers at all. They rely on the resiliency of the planked floats and their vee-shaped entry to dissipate the taxi-ing and alighting shocks.

If the rear chassis struts embody the shock absorbers it will be necessary to keep the fuselage supported by a trestle beneath the strut attachment point whilst the remainder of the erection is proceeding.

Screwed couplings or short projecting pipes are fitted to each compartment of seaplane floats to allow for changes of pressure with change of altitude, and the necessary piping must be coupled to these and run up the chassis struts clear of the water.

The rigging diagram or instructional chart should be carefully consulted for such details as this and for all dimensions, etc. Having assembled the float chassis to the fuselage, the alignment should be checked by diagonal measurements from axle ends to stern post and prop boss centre lines.

The superstructure erection will be as for land machines and calls for no special comment. The centre section will be erected first, in fact this might with advantage be done before raising the fuselage up to receive the chassis, as the lifting slings will then possibly be of use for this purpose.

The tail float (if any) may be mounted on a chassis or may fit direct to the underside of the fuselage. There will probably be a water rudder to link up with the controls. If the float is on a wire-braced chassis the rigging angle will need to be obtained from the rigging diagram. Wing tip floats (if any) may be of the inflated balloon fabric, moulded cork or the more modern boat built type. Their assembly to the lower planes should present no difficulty. If, as is sometimes the case, they are stayed laterally by bracings, it is well to remember that they should be rigged with an outward rake so that when the machine heels over the float will strike the water in the attitude giving maximum displacement on contact. The rigging diagram will most probably give an angle at which the floats should be set.

Most seaplanes have folding wings and immediately after rigging they should be folded and then re-spread to see that the supports on the aft portion of the fuselage will engage with the fittings provided on the planes, and also to ensure that the spar joints will re-engage without binding. Before folding the wings make sure that the tail is adequately supported at the proper trestling points, as marked on the fuselage and/or rigging diagram.

In recent years seaplane floats have been built of duralumin and this material, if properly protected against corrosion, has a great advantage over wood for this purpose.

Metal floats do not soak up water as do wooden floats. The turtle back type of float is much in favour for construction in duralumin, as the curved deck plating has tremendous inherent strength and there are fewer joints to make watertight.

(*b*) Boat Seaplanes

Boat seaplanes, or flying boats as they are more commonly called, are seaplanes in which the landing chassis and fuselage are combined in the form of a hull. They have been built with one, two, three, four and five engines, but the commonest form is the twin-engined type.

The late Colonel John C. Porte was in 1914 preparing for a trans-Atlantic flight on a flying boat called the "America" when the war broke out, and this officer thereafter did more than any other individual for the developing of the boat seaplane. He was in charge of the Seaplane Station at Felixstowe and there produced the F2a and F3 flying boats—many hundreds of which were built and used during the war.

There are two main types of boat seaplane:—

(*a*) The "long hull" type in which the tail unit is mounted on the stern of the hull.

(*b*) The "short hull" type in which the tail unit is carried by outriggers.

Type (*a*) is the more popular and is more seaworthy than type (*b*), at any rate in the smaller sizes. Type (*b*) is less stable fore and aft when riding at anchor, and in rough seas there is danger of the tail units being damaged.

Type (*b*) may be represented by the Sopwith "Bat Boat," which won the Mortimer Singer Prize as an amphibian in 1913. The Americans have also produced this type in the N.C. series, one of which was flown across the Atlantic in May, 1919.

Flying boats of larger displacements are being produced year by year, the latest reported being one built by the Zeppelin Co., which, it is stated, can carry 60 passengers, and has attained a speed of 120 miles per hour.

Before outlining construction, it will perhaps be of interest to consider briefly the data on which flying boat hull design is based.

General Considerations

The first essential is to know the total displacement and this is required to be at least four times the fully loaded weight of the machine. This displacement is calculated to the lowest point of the lowest opening which cannot be made watertight during flight. The next main consideration is to decide the hull length and the beam of the planing bottom at the main step. The position of the wings relative to the hull is then decided and a model made and tested in the Froude tank to decide whether the external form chosen gives the necessary degree of stability and clean running.

Lines

The planing bottom is usually vee-shaped in cross section as this serves to absorb the shock when alighting on the water as well as imparting lateral stability when taxi-ing.

The body plan is really an end view of the hull showing the outline of sections taken at regular intervals along the hull length. One half of the body

plan shows the half sections forward of the main step and the other half those abaft this point. Vertical lines are drawn at intervals of about 10in. and these are called buttock lines, whilst the horizontal lines at about 6in. intervals are termed water lines. It is usual to draw at least two diagonal lines extending from the centre line downwards and outwards.

The reason for these lines is to define the exact form of the hull. The planing bottom of a hull is carefully shaped in order to ensure efficient and clean running as the machine is taxi-ing to take off, and to ensure the lines of the machine being exactly as on the approved model it is necessary to prepare a table of offsets giving the distance from certain datum lines to the points where the buttock lines, water lines and diagonals intersect the hull cross sectional outlines on the body plan.

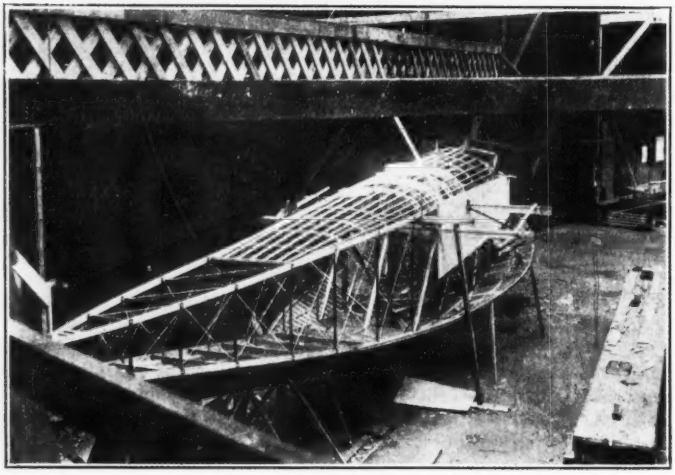
These lines after being drawn on paper are then laid down full size on what is called a mould loft, this being merely a black painted floor which serves as a huge drawing board. From this full-sized layout the shops make up keel moulds and frame moulds around which the hull skeleton is built.

Hull Construction

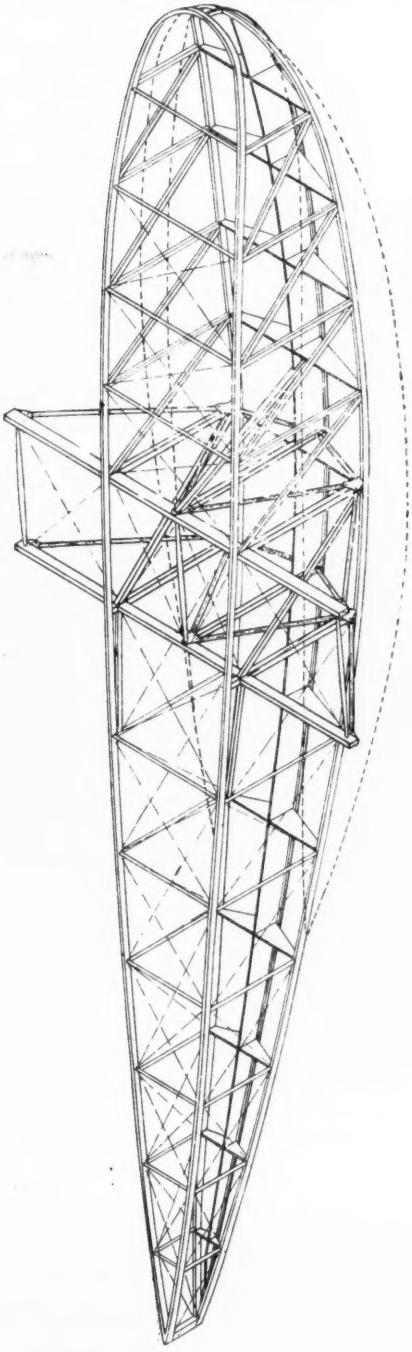
There are two main forms of hull construction :—

(*a*) The rigid type.

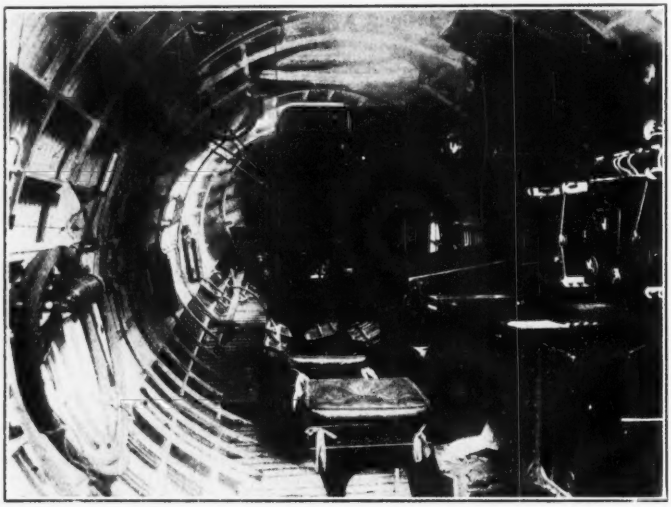
(*b*) The resilient type.



The hull framework comprises four longerons with vertical and horizontal struts and bracings, and from the main structure project the floor frames and keelson carrying the planing bottom. Modern practice in wooden hulls is tending towards type (*b*) as developed by the late Major Linton Hope. The basis of this type is that the hull is built on a number of hoop frames of approximately circular form. These hoops are at intervals of one to three feet and around them are fore and aft stringers with a spacing of 4in. to 10in. Outside these stringers and running circumferentially are the timbers at 1½in. to 3in. pitch to which the planking is attached.



Built on this inner shell are the frames carrying the fin chines and planing bottom. The planking is usually of mahogany; occasionally single skin of say $\frac{1}{8}$in. to $\frac{1}{4}$in. thickness, in which case the planks are worked fore and aft with the seams arranged central with the stringers so that the plank edges make a joint thereon. The timbers in this case are let in flush with the outer face of the stringers. This is known as carvel stringer construction. The outside of



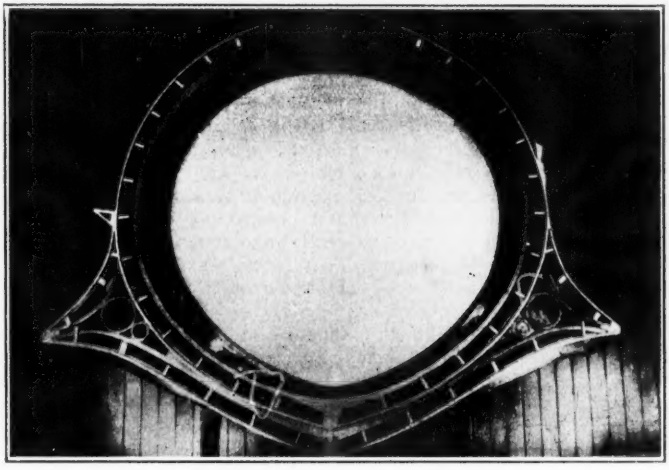
the planked hull is then covered with fabric glued in place and painted over. This single skin construction is only suitable for small light craft. The more usual form is the double skin type. The inner layer of planking runs diagonally whilst the outer strakes are usually run fore and aft, but may sometimes be run diagonally to the inner skin. Between the two skins varnished fabric is placed to help keep the water out and to protect the planking. Through fastenings in the form of copper nails are used for securing the framework and planking.

Sometimes a material called "Consuta" is used for planking the rigid or box type of hull. Consuta is the invention of Saunders, the boat builders, and comprises two skins of planking of either spruce, cedar, or mahogany, machine-sewn together with waxed threads. It can only be used for flat or single curvature surfaces, but recently Saunders have endeavoured to use it on double curvature planing bottom by sewing it in place by hand.

The Linton Hope form of hull construction is in my opinion superior to the other forms, as there is a degree of resiliency which has been proved to be very advantageous for withstanding water shock. In addition to this superiority there is the further advantage that the interior of the hull is free from cross bracings. It further lends itself to the provision of a double bottom. The usual form comprises a main hull body carrying a planing bottom on formers of some 2in. minimum depth. The space between the main hull shell and the planing bottom is divided fore and aft by the keelson and athwartships by a number of watertight bulkheads. The size of these watertight compartments is such that, should any one of them be holed and flooded, the remaining buoyancy is sufficient to keep the aircraft afloat without dangerously impairing the stability or trim. There are two steps on modern hulls—one amidships round about the fore and

aft C.G. and the other further aft. At the main step the planing bottom reaches its maximum beam. The aft step is usually deeper than the main step in order to keep the after part of the hull and the tail unit clear of the water.

Just before taking off from the water a boat seaplane is planing on the surface at a speed of say 45/50 knots and at this time the portions of the hull which are immersed are round about the steps. The wave shock under these conditions is considerable and it will therefore be understood that the planing bottom needs to be stronger than the main hull shell and the strongest portion is about the main step.



Erection

Hull Slinging and Support.—Whenever possible the hull should be supported on a shaped cradle of such a size as to distribute the weight of the machine over about one third of the planing bottom area. It is usual for hulls to be transported and stored on a framework comprising formers faced with padded laths shaped to suit the planing bottom curvature for a distance of say 6 to 12 feet amidships. This cradle usually has its base extended for slinging purposes. When a hull is being prepared for the superstructure it is usual to support it on the launching trolley—this being a cradle as already described, but mounted on a steel sub-frame provided with wheels.

When lifting a hull it may be found possible to sling direct from the fitting provided to take the stay tubes to the lower planes. If the wing roots are built integral with the hull, slings can be attached to the fittings thereon. Alternatively, a beam should be secured along the hull top by means of lashings through the cockpit openings. Rope slings encircling the hull can of course be used providing that their position is clear of the cradle. In this case packings should be inserted where the ropes cross the keel and chines.

Setting up the Hull.—The method of setting up the hull ready for the superstructure varies with different types. In most hulls of the Linton Hope type the hull top is level for some portion of its length and this forms the datum line. In some cases the lower planes are set on the hull top, whilst in others the lower centre section is " built in " so that the front and rear spars pass right through and at their extremities are the attachment fittings for the lower outer planes.

If the wing roots are built integral with the hull, as in the "F" boats, the levelling up should be done from the wing root spars inside the hull. If the lower centre section is a separate component the hull should be lined up fore and aft from the datum dine, as shown on the rigging diagram. Athwartships level can be checked by dropping a plumb line from the centre of the top member inside the hull and this should of course line up with the centre of the keelson. The lower centre section is then mounted, levelled athwartships and the wing root stay tubes and bracing wires fitted.

Engine Mountings.—The next process is to erect the engine mounting or mountings which are usually over the hull top and/or wing roots. Assuming that the engine has been removed from the mounting for transport, the engine bearers will now be levelled up fore and aft and athwartships by the use of straight edge and spirit level. The alignment of the bearers with the centre line of the hull will next be checked—bearing in mind that some designers provide for setting the engine to port or starboard to compensate for torque reaction, due to slipstream whirl effect on the fin and rudder, *e.g.*, Fairey IIID $1\frac{1}{2}°$ to port, "Southampton" 4° to port for both engines. On some machines the engine mountings can be erected without the upper centre section in place, but on others it is necessary to rig this component in order to complete the structure. Consult the rigging diagram for the particular machine on this point. After installing the engine, plumb lines should be dropped from centre of propeller shaft and centre of engine at the opposite end and thus the fore and aft alignment can be checked with the hull centre line. In the case of outboard engines the diagonal measurements should now be taken from the engine mountings to the stern post and to the towing eye or drift wire fittings at the stern. If the engines are of the radial type a straight edge should be clamped level and central across the engine plate and diagonals taken from its centre or ends to the stern post. Port and starboard engine plate centre lines should, of course, be in alignment with each other athwartships. As soon as the centre section and engine mountings are rigged, it will be advisable to fit jacks or trestles under the wing roots in order to take the weight, as if the hull is of the resilient type it will deform slightly. Jury stays are sometimes provided to pick up a fitting at each wing root spar joint and to engage with another fitting on the launching trolley sub-frame. The remainder of the power plant installations can now be proceeded with. In the "F" boats the main petrol tanks are inside the hull, but many of the more modern machines carry the whole petrol supply on the upper centre plane. In the case of water-cooled engines, the reserve water header tank is often mounted in the leading edge of the upper plane. The oil tank is almost invariably mounted on the engine mounting itself. The connecting up of pipe systems, engine controls, etc., calls for no special comment. The same precautions as for a land machine apply equally here.

Tail Unit

Tail unit erection should present no particular difficulties. The tail fin is usually larger than for a similar land machine and there is generally at least one strut passing through the hull top planking and picking up a fitting on the keelson. The tail plane is commonly of the monoplane type and carried half way up the fin, well clear of the water. It is sometimes of the inverted camber type, *i.e.*, a normal wing section placed upside down. The reason for this is that the engines are necessarily mounted some distance above the hull to keep the propellers, etc., clear of the water and this produces a high thrust centre line and so a tendency to nose dive. This tendency is accentuated by the effect of the large forebody of the hull. This is necessarily large in order to provide ample buoyancy forward to prevent "nosing in" when alighting. The weight and resistance of this large body below the centre of thrust has to be counteracted

by a constant down load on the tail and the inverted tail plane is the best way of doing this.

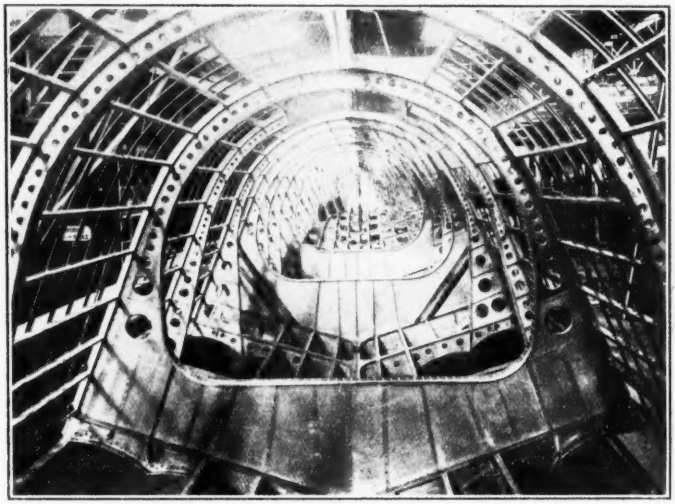
Main Planes

The lower plane of a flying boat is often of less span than the upper for three reasons :—

(*a*) There is less risk of damage on the water.

(*b*) The stresses imparted to the wing tip floats are more easily catered for.

(*c*) Ailerons, if fitted to the lower plane, are liable to damage by rough seas. They are, therefore, fitted to the top planes only and lateral control is usually quite effective as the ailerons are carried further out so that some portion at any rate is working in air undisturbed by the lower plane.



The erection of the main planes calls for no particular comments as the precautions and methods described in a previous paper on the erection of land machines apply equally here. In cases where lifting tackle is available, it will be found easier to box the planes on the ground. The wing tip floats may also be assembled to the lower planes before the wings are lifted providing they do not project forward of the leading edge.

These floats will no doubt require an outward rake as mentioned for float seaplanes.

Care of Planking

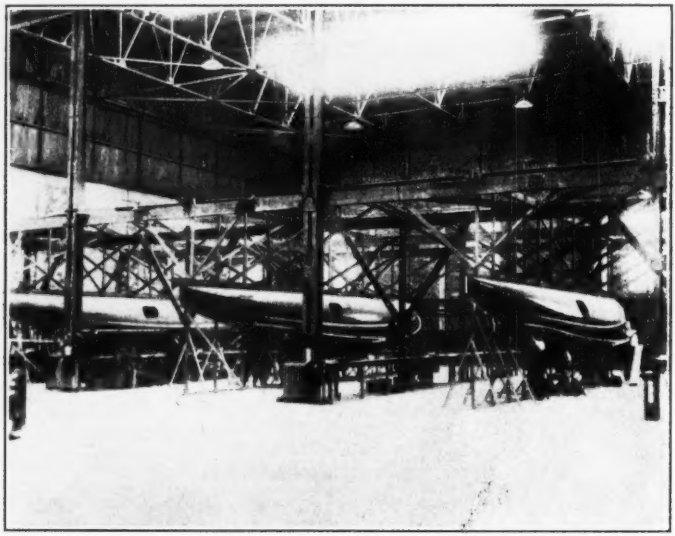
If it is found that the hull planking (due to long storage) is opening up at the seams, damp cloths should be placed thereon and wet sawdust on the floor. Water may be pumped into the hull bottom as there is always a bilge pump fitted to the machine for emptying this later on.

These precautions apply more particularly to the rigid, single shell type of hull as due to the mixed construction involving tubular struts, etc., in conjunc-

tion with a timber shell there is unequal expansion and contraction. This is another reason for my preference for the Linton Hope type as the whole shell can deform in unison as the timber shrinks or swells.

Metal Construction

During the past few years duralumin has been used for flying boat hulls and this material is likely to increase in favour for this purpose because, by its use, we can avoid the great increase in weight due to the water absorption experienced with wooden hulls. It has been found that 600 lbs. of water have been soaked up by a wooden hull of some 16,000 lbs. displacement. The modern tendency is for flying boats to be kept afloat for the greater part of their time as there is a considerable risk of holeing a hull when endeavouring to float the



machine on its trolley in rough weather. It is probable that a metal hull will be less liable to serious damage by floating wreckage, etc., and by bumps when handling, as the plating would, no doubt, be merely dented and bulged by blows which might hole a wooden hull. The main difficulty with duralumin is of course its liability to corrode when in contact with sea water and spray. The best protection is afforded by anodic treatment, the electrolytic process developed at the R.A.E., but this is expensive because of the large plant needed and because of the delays involved in shaping and fitting component parts and then having to remove them for treatment. The next best protection is afforded by a good quality white enamel, and this is now used extensively. Even wooden hulls are white enamelled below and about the water line to prevent the fouling which accompanies long immersion and of course to help in maintaining water-tight joints.

The seams of metal hulls are double or treble riveted lap joints with a plastic lacquer used as a bedding.

The metal hulls so far constructed have been of the single shell type; that is, without double bottoms. The reason is primarily that it is very difficult to

build the planing bottom on the main hull without the use of elaborate riveting tools or a large number of set screws instead of rivets. Moreover, it has been claimed that with the metal hull there is less need of a double bottom for reasons already mentioned.

In any case it is quite feasible to make a single shell hull and provide for the floor plating to be watertight.

There are a few special types of flying boats which I have not yet mentioned.

1 The Rohrbach

This is a twin-engined monoplane with rather large side floats placed beneath the wing engines, *i.e.*, fairly close to the hull. These floats are of course to preserve lateral stability. They are so placed in order to obviate the heavy stresses in the monoplane wing spars which would accrue if wing tip floats were used. The construction is of duralumin, but the hull design is poor.

2 The Dornier Wal

In this case also the wing tip floats are dispensed with, but to preserve lateral stability afloat there are two root planes extending from the hull planing bottom. These stub extensions are so shaped as to assist in taking off and it is claimed that a certain amount of aerodynamic lift is obtained from them.

3 The Twin Hull Savoia S.55

This is a thick wing monoplane with two engines mounted in a central nacelle. The pilot and crew are situated within the thick centre section whilst passengers are accommodated in the two hulls. The tail unit is carried on outriggers.

In conclusion, I would like to say that in my view there is a great future for the flying boat. In its larger sizes of say 10 tons and over, the weight and resistance of the hull is no more than that of the fuselage and landing chassis of a similar sized land machine. I also consider that the Linton Hope form of hull construction could with advantage be used for fuselage construction. For commercial work it has great advantages due to the freedom from internal cross bracings and the fact that, if forced to descend on the water, the machine would remain afloat much longer than would the types now in use.

GLUES

Paper read at the 12th Meeting for prospective Ground Engineers, held at 7 p.m. at the Westland Aircraft Works, Yeovil, on the 26th January, 1927.

BY H. BURDETT

(OF MESSRS. THE IMPROVED LIQUID GLUE CO.).

The motor trade with its many branches, such as lubricating oil, petrol, etc., the metal industry and the glue trades owe much to the aircraft world. This is not fulsome flattery, but merely a statement of facts.

In spite of the importance of glue to industry as a whole it was not considered of any significance until the aircraft constructors started in real earnest to convince the whole world that Great Britain could build the finest air fleet as well as the finest fleet of ships—not only for protection but also for passenger service.

In keeping with the precautions for our safety taken by our much maligned Government, the A.I.D. came into being, this constitution acting as Lloyd's do for our ships, or the Board of Trade for passenger-carrying vehicles on land.

Previously, and even to-day in many trades, glue is simply glue and purchased strictly on a price basis without reference to its capacity for endurance or strength; the lives of many men practically speaking depending on the quality of the glue used altered this on the instant, and caused manufacturers of glue to sit up and take notice.

I can imagine the feverish anxiety that followed the laying down of the standard known as British Engineering Standard 2.V.10 for liquid and jelly glues. Research work into glues, which is still being carried on with certain firms, dates practically from this.

This attitude of indifference to a matter of real importance is perhaps not surprising. Glue is not a topic for every-day conversation, unless it be amongst users of glue. I must confess to complete ignorance of glue and its uses until I came in touch with the peculiar difficulties of selling and manufacture.

As a matter of fact, I am surprised that so many of you turned up to-night to this lecture. I am so used to the general public's attitude to glue that it is extremely refreshing to find anyone interested enough to come prepared for what so many people would term sixty minutes of boredom.

Even my own friends look upon my occupation as somewhat of a joke—much to my amusement; whereas if you look round this room there is hardly a thing in which glue does not enter. The Company I represent has a list of 75 trades to which they actually supply glue, and each month almost finds another new and interesting trade to add.

One of the most curious uses I personally have encountered is that of a pork butcher in a north country town. For some time now we have supplied him regularly with glue, and when in the North I made it my business to call with the object of finding out for what purpose he used the glue. He seemed very pleased to see me, and after the usual hedging asked if there was anything in our glue that would be detrimental to human beings.

It appeared the new food adulteration laws had been worrying him as he was painting the tops of pork pies with glue. However, I was able to reassure him on this point. Gelatine which is one remove from glue is used in a number of edible products. Please do not think for one moment, however, that I am suggesting you should substitute "Croid" for your daily ration of Spearmint.

Of the several kinds of glues manufactured, the two most commonly used in the woodworking trades are:—

1. Casein glues.
2. Animal glues.

Casein glues have for their base casein, which is a product of milk bearing a close relation to cheese. There is three per cent. casein contained in milk.

Very little was known about these glues until the advent of aeroplanes. Previously casein had been used for coating and sizing papers principally. In 1918 research was made into the different properties. This work is still being carried on and many patents have been taken out with a view to improving manufacture.

The present improved method of obtaining the casein is to heat the milk to a temperature not exceeding 96°F.; the cream or fat is then skimmed off, acids are added which cause the casein to separate, the whey is drawn off, and after washing to free from acids the casein is put into presses to squeeze out the moisture.

The cakes are broken up to facilitate drying, placed in drying tunnels in trays and submitted to currents of air heated to a temperature of 125°F.

To make up casein glues, the casein is ground to 90 or 100 mesh, placed in a mixer, chemicals being added (the chemicals are necessary as casein itself is insoluble in water). The result is a white powder soluble in cold water, for which many advantages are claimed over other glues, mainly in that it is heat-proof and damp-proof.

There are unfortunately certain distinct disadvantages that prevent universal adoption of casein glues. In the first place they stain hardwoods, as mahogany; secondly, when the joints are sawn or planed the hard cement blunts the tools; and thirdly, they require more careful handling than is to be expected from the average workman.

To quote an instance personally investigated, one of the London A.I.D. inspectors 'phoned through saying he had condemned certain articles owing to the faulty casein glue. This being serious, both for ourselves and the customers, I called at the factory to inspect the glue.

This appeared to be in order. It was passed out under the usual A.I.D. Release Note. On going further into the matter I was informed by the foreman that he mixed two proportions of water to one of casein cement by measure.

Now, it distinctly states on our instructions that all measurements for "Insol" casein cement must be by weight, and we had taken the precaution to repeat all instructions by sending down a supply of leaflets. The foreman's reply was typical of that type—he did not think it mattered; besides, "we ain't got no scales." Happily his boss did not agree with his ideas.

The second class of glue mentioned, viz., animal glue, is the most important from a consumption point of view. This glue is one of the most difficult problems to produce in anything like good and consistent quality. All sorts of snags await you, even to finding the most suitable site for your factory. You might strike an ideal spot only to have injunctions served upon you by the near neighbours, and believe me, I would not live within smelling range of a glue factory, especially on a sultry day.

Dealing with manufacture, one of the first of life's little worries is water supply. This must be copious; the water itself must be free from iron and not contain an excess of mineral salts or sulphuretted hydrogen, with plenty of scope for discharge waters without unduly polluting your neighbours' supply.

As an instance of the importance of commercially pure water supply, owing to the pollution caused by the discharge waters from a large chemical works, a glue works in Cheshire has had to close down entirely.

You will understand this question of water supply more easily perhaps when it is stated that upwards of 1,000,000 gallons of water per day are required for an average size glue factory; or again, from the fact that glue itself is an excellent medium for breeding bacteria, and should the water used in washing be contaminated, the whole of the glue manufactured would be infected and rendered useless.

Of secondary importance is the air supply, as, in the evaporating and drying tunnels, one ton of air is required to extract 1 lb. dry glue from the glue jelly. Here again there is an ever-present risk of infection of the glue stock during the drying-out process.

Now with regard to the collection of raw products, these must not be unduly delayed in transit—whether by road or rail—or the different authorities are liable to get hot under the collar and let off a lot of steam; and if you have in your travels met a consignment of hides or bones en route you would scarcely blame them.

Actually, glue manufacturers must be a boon to mankind in the fact that they provide a remunerative means of disposing of the bones and refuse from slaughterers and leather dressers, which might otherwise be allowed to collect, and by the attraction this offal has for flies, easily spread disease.

The oldest form of animal glues was made from hides. There is in the British Museum a stone carving from the animal city of Thebes depicting the Egyptians laying veneers with glue which must be at least 3,300 years ago. The earliest practical manufacture of hide glue was in 1690 in Holland, and in England about ten years after. Bone glues were made first about 1814.

As a result hide glues were, until quite recently, looked upon as superior in every respect to bone glues, and until investigations caused by the requirements of the aircraft industry for a really high standard of glue in contrast to the usual attitude towards glue, no one questioned this theory. This reputed superiority has proved to have no foundation in fact.

The essential qualities of a good glue are :—

(1) The strength, which should be as great as the wood itself.
(2) Resistance to atmospheric conditions.
(3) Ability to withstand normal conditions of ordinary workshop practice.

Formerly, only the best hide glues fulfilled these requirements. The manufacture of glues from bones was very primitive, and consisted of boiling out the glue from the bones in open coppers. As a result, the glue was contaminated with fat, degraded gelatin and muscle matter.

Its unsuitability for joining hardwood can be imagined. The fat prevented the glue soaking into the wood, the overheated gelatin made it sensitive to damp, and the impurities caused the glue to quickly putrefy.

Bone glues were therefore relegated to cardboard box manufacture and similar trades, where great strength is not so important as price. However, the glue industry has made large strides in technique in recent years.

In up-to-date British factories the bones are completely freed from grease and adherent tissue; therefore the glue itself is manufactured from a practically pure source—a further notable improvement is that glues are not simply sold as glues, but regularly tested for viscosity, jelly strength, acidity, foam, etc., and carefully graded according to the result obtained.

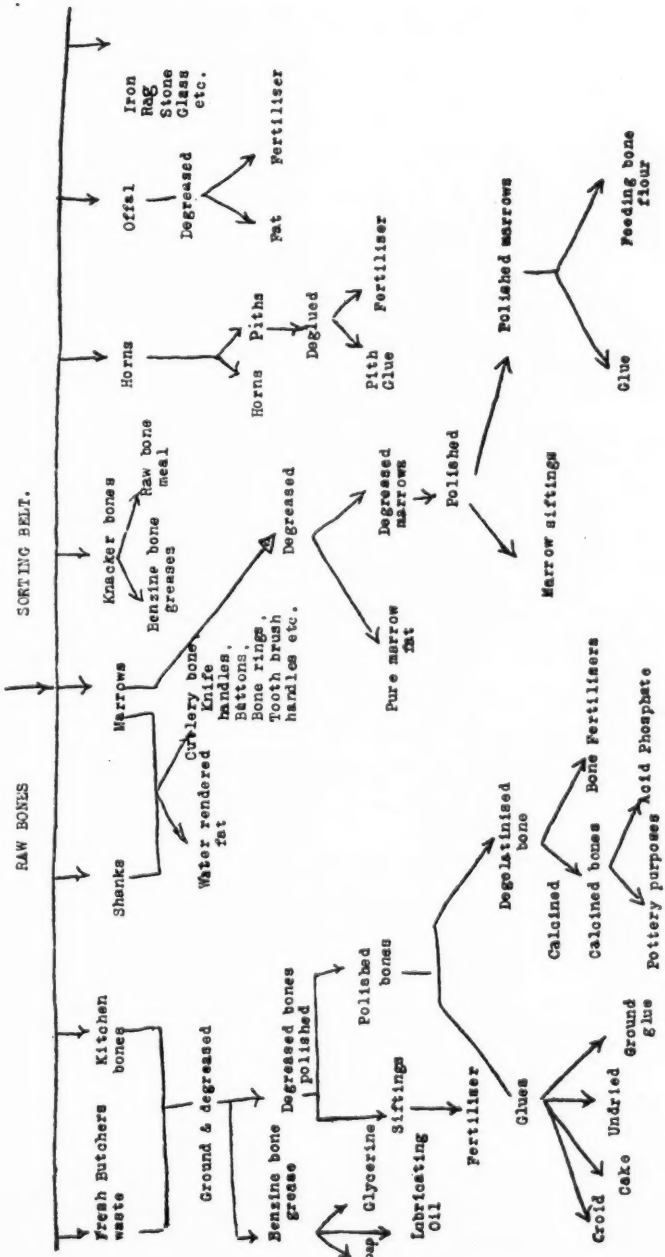
As a direct result of these investigations it is definitely proved that the highest grade of bone glue is as good in every respect as hide glue, particularly for hardwoods. It is of especial interest that the Air Ministry has recognised this, and now includes bone glues in the A.I.D. Specification, the main factor of which is a tensile strength of 1,100 lbs. to the square inch for walnut shear joints.

This is hardly surprising having regard to the tremendous strains to which the bones of animals are subjected throughout life, and to the fact that the ability to withstand such strains entirely depends on the robustness of the glue-forming matter contained in the bones.

It is perhaps necessary at this stage to define what is meant by high quality glue. This should consist of a protein gelatine not unduly contaminated by the heat degradation products, proteose and peptones. A good glue is enormously strong—a thin film of dry glue needs 11,000 lbs. tension to tear it apart. Similar films of celluloid, resins, etc., are much weaker.

In making comparisons between glues, however, we must consider the suitability of the glue to the wood, rather than the abstract strength of the glue film alone, and when dealing with hardwoods viscosity counts for everything. Bone glues are of a lower viscosity, and will therefore penetrate more rapidly and further into the wood; whereas hide glues require greater dilution by water to reach the same viscosity and therefore require much more time to dry out with a risk of the glue being too weak.

Resistance to atmospheric conditions is a matter of extreme importance. Glues made by boiling out fresh bones direct often contain hygroscopic salts, which weaken the resistance of the joints; also the presence of proteose and


RAW BONES
SORTING BELT.
Fresh Butchers waste
Kitchen bones
Ground & degreased
Benzine bone grease
Degreased bones polished
Soap
Glycerine
Lubricating Oil
Polished bones
Siftings
Fertiliser
Shanks
Water rendered fat
Marrows
Cutlery bone Knife handles, Buttons, Bone rings, Tooth brush handles etc.
Degreased
Knacker bones
Benzine bone greases
Raw bone meal
Pure marrow fat
Degreased marrows
Polished
Degelatinised bone
Glues
Croid
Cake
Undried
Ground glue
Calcined
Calcined bones
Bone Fertilisers
Pottery purposes
Acid Phosphate
Marrow siftings
Horns
Horns
Piths
Degreased
Degreased
Offal
Iron
Rag
Stone
Glass
etc.
Fat
Fertiliser
Deglued
Pith
Glue
Fertiliser
Polished marrows
Glue
Feeding bone flour

peptones, which are soluble in water, is another source of trouble. Present-day manufacture provides for the removal of these impurities.

Another important point which glue manufacturers have to guard against is overheating at any stage of manufacture. It has been established by analysis that a glue of 1,100 lbs. tensile strength, which has become hydrolised by heat, will fall to a strength of 600 lbs. and become completely soluble in water.

Hide or Skin Glues.—Here is a short description of the method commonly used in the manufacture of hide or skin glues.

On receiving the skins, the first care is to wash them by soaking in lime baths. This has the effect of loosening the hairs and saponifying the fat.

After liming, the skins are washed with dilute acids to hasten cleansing, then placed in vats and covered with water brought to a temperature of 140°F., when the liquor is drawn off and fresh water added and drawn off, each tapping being carefully filtered to remove undissolved organic matter.

This operation is repeated four or five times, each time the temperature is raised 10 degrees; but on no account must it be allowed to exceed 212 degrees or the glue liquor would become degraded. From careful observations made at this stage it is found that while the viscosity of the glue liquor rises in direct proportion to the heat, the jelly strength remains almost constant between 140 degrees and 160 degrees, above which it gradually drops. Therefore, the manufacturer who is careful of his reputation grades his glue strictly on jelly strength.

The glue liquor is submitted to evaporation in vacuum pans, and then exposed to refrigeration. At this stage there is a great risk of infection by bacteria, engendered by the foggy atmosphere, which is an ideal one for breeding germs.

The glue is now cut into sheets which are placed in drying tunnels, great care being exercised to maintain a constant temperature. Two degrees either way would do incalculable harm—if too dry the glue would be brittle, if too moist the glue would absorb the moisture. Also care must be taken to exclude dust; absolute cleanliness is essential to good glue; infected glue liquefies and has a very low tensile strength.

Bone Glues are manufactured in the following manner:—

The raw bones, which are collected from butchers, marine store dealers, slaughterers, etc., are carefully sorted and graded according to their glue-producing qualities, coarsely ground and degreased.

Degreasing takes place in vats of 10 to 15 ton capacity. These vats have perforated false bottoms, under which are steam coils; benzine is evaporated up through the bones, the grease and benzine is then drawn off, leaving the bones practically free from grease and moisture.

The bones are now taken from the vats, passed over magnets to remove any iron not removed in sorting, as rust of any kind seriously affects the glue, and polished in rotating drums fitted with perforated covers, which allow the fine dirt and hairs to fall through.

The polished bones are deglued by treatment with steam and hot water, the glue liquor being drawn off and treated in the same careful manner as described for the hide glue manufacture.

A word now as to the check system so essential to good glue production to guard against the many causes for failure, chief of which are:—

1. Overheating.
2. Moisture in storage rooms or drying tunnels.
3. Bacteria.
4. Rusting iron which stains the glue.
5. Impure water.
6. Contaminated air.
7. Grease.

We have one of the most completely equipped laboratories for testing and grading all glues manufactured. Perhaps the following list of tests regularly made will give you some idea of the work carried out :—

1. Jelly strength test.
2. Viscosity test.
3. Melting point test.
4. Tensile strength test.
5. Adhesive strength test.
6. Elasticity test.
7. Swelling capacity test.
8. Foam test.
9. Grease test.
10. Setting test.

In spite of this costly research work and also the many improvements in the method of manufacture, the majority of glue users retain the centuries old practice in making up their glue, in many cases even using price alone as a guide when buying glues. Yet these same firms often employ trained mechanics to develop efficiency and scrap unsound methods.

When one considers the risk of trusting to the judgment of a foreman who may not have advanced beyond the stage at which his predecessors left off, it is hardly surprising that little or no progress has been made.

Here are some of the quite common reasons that produce faulty glue in the workshop.

Storage Conditions

If cake or powder glues are stored in a damp atmosphere they will absorb moisture and thus alter the amount of water that should be added to produce a given strength.

Breaking Up

The usual method is to pound up the cakes inside sacks. This often introduces dust and grit into the glue, apart from the fact that unless the cakes are evenly broken up it is liable to cause lumpy glue, as any large pieces would take more time to dissolve.

Measuring Water

The common practice of measuring by bucket and not by weight cannot be too severely condemned. A miscount may easily occur or a shortage in each or every bucket would considerably affect the viscosity of the glue.

Soaking

Plenty of time should be allowed and the whole of the glue must be completely covered with water. Unsoaked glue requires great heat to melt, which might result in the whole glue being overheated.

Overheating

It has been proved that glue boiled all day loses in tensile strength 85 lbs. per square inch each hour.

Viscosity

This should be consistent. A cold glue is too thick and has no penetration; overheated glue becomes too thin. Workmen will often add cold water to their glue to suit their own ideas, or to make up the water lost by evaporation, and so lessen the actual glue content, which may have been previously correct.

Bacteria Action

Absolute cleanliness should be observed; all brushes and glue pots should be scrupulously cleaned after the day's work, and all unused glue thrown away. Infected glue has a low jelly strength and a low melting point.

Water Supply

This should be reasonably pure; if any iron salts are present it would cause discoloration and result in staining.

With all these factors to contend with, it will not surprise you to learn that glue users who value their reputation are turning over to liquid glues, as these glues are practically foolproof, being supplied in a scientifically-prepared state, with a greater covering capacity and tensile strength entirely immune from bacteria action, enabling the merest tyro to make a joint equal to the most expert workman.

A great deal of time and money has been spent in producing a liquid glue with the reputation "Croid" has. I say this with every conviction, and perhaps you will agree when I state that in the fifteen years "Croid" has been on the market, we have had to move four times, each time to larger factory premises; or again, from the fact that in London alone in the past six months we have increased our sales over the previous six months by 3,000 pounds sterling on "Croid" alone, and this in spite of the depression caused by the coal strike.

I regret I cannot give details of the manufacture of "Croid," as this is a jealously guarded secret. However, I can describe the method of a competitor who recently closed down. In this case, cake glue of foreign make was purchased, broken up, placed in a large cauldron, water, fish glue and carbolic crystals being added, and the whole mixture stirred by hand with a large wooden paddle.

This description of how *not* to make a liquid glue is by no means an isolated one or exaggerated; we know of others, and by comparison, the "Croid" method seems extraordinarily complicated.

In the first place it is impossible to obtain standardisation unless you manufacture from the raw bones or hides.

Secondly, we do not have to add fish glue to "Croid" to give it an artificial tackiness, and make up for the high moisture content.

Thirdly, our mixers have a capacity up to three tons, and all operations are conducted by automatic machinery with a view to eliminating the human element.

In concluson, I would say that "Croid" is entirely a product of British brains, manufactured in England, employing British capital and labour throughout. A fact of which we are naturally proud is that we export quite regular consignments to U.S.A. and other foreign countries, who have a reputation for being first in the field with all inventions.

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The Control of Stalled Aeroplanes	B. Melvill Jones	June, 1926
Notes on Stalled Flying	C. Howarth	June, 1926
The Tailless Aeroplane	Capt. G. T. R. Hill	September, 1926
Sustentation in Flight	F. W. Lanchester	October, 1926
Bernouilli's Theorem in Aerodynamics	M. S. Hooper	October, 1926
Stalled Flying	S. Scott-Hall	October, 1926

Airscrews

The Screw Propeller in Air	M. A. S. Riach	April-June, 1917
The Dynamics of Fluid Propulsion	M. A. S. Riach	August, 1918
A Note on the Theories of Screw Propulsion	H. C. Watts	July, 1920
Some Fundamentals of the Theory of Blade Screws	G. de Bothezat	November, 1920
A Note on the Inflow Theory of the Airscrew	M. A. S. Riach	January, 1921
The Fan Propeller and Blade Interference	M. A. S. Riach	February, 1922
Stresses in Airscrews due to Varying Engine Torque	John Case	August, 1922
The Vibration of Airscrew Blades	J. Morris	December, 1922
Review of Airscrew Theories	A. R. Low	February, 1923
The Effect of Variable Gearing on Performance	Annie D. Betts	November, 1923
Airscrew Vibration and Gear Stripping	J. Morris	August, 1926

Airships

Lighter-than-Air Craft	T. R. Cave-Browne-Cave	July, 1919
The Principles of Rigid Airship Construction	A. P. Cole	March, 1920
Rigid Airships and Their Development	J. E. M. Pritchard	April, 1920
Airship Machinery	C. F. Abell	May, 1920
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Fluid Resistance on Streamline Bodies	J. R. Pannell	September, 1920
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Airship Mooring by "Free" Wire Systems	R. A. Frazer & L. F. G. Simmons	February, 1921
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The Present Technical Position of Airships	G. H. Scott	January, 1922
The Aerodynamical Characteristics of the Airship	R. Jones	February, 1924
The Effect of Meteorological Conditions on Aircraft	G. H. Scott & V. C. Richmond	March, 1924
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Review of Present Position of Airship Research and Experiment	Colonel V. C. Richmond	October, 1926
Calculation of Stresses in Hulls of Rigid Airships	R. V. Southwell	November, 1926

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The Design of Aeroplane Struts	W. H. Barling and H. A. Webb	October, 1918
Struts of Conical Taper	H. A. Webb & Miss E. D. Lang	April, 1919
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Possible Lines of Development in Aircraft Engines	H. R. Ricardo	March, 1921
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History

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The Static Head Turn Indicator for Aeroplanes	Sir Horace Darwin	December, 1919
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Some Recent Developments in Aircraft Instruments	H. E. Wimperis	Jan. & Feb., 1924
Practical Navigation of Aircraft	Captain F. Tymms	May, 1925

Materials

The Less Satisfactory Materials of Aircraft Construction	G. S. Walpole	Jan.-March, 1917
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Timber: Its Identification & Mechanical Properties	W. H. Barling	May, 1918
Shop Practice in Respect to Aircraft Steel	H. P. Philpot	March, 1919
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The Case for Metal Construction	J. D. North	January, 1923
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Metal Aeroplane Construction	Hugo Junkers	September, 1923
Some Materials in Aircraft Construction	J. D. North	April, 1924
Materials in Aircraft Construction	L. Aitchison	April, 1924
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Some Remarks on the Proof Stress	E. Skerry	May, 1926

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Some Medical Aspects of Air Transport	C. B. Heald	June, 1925

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The Meteorology of the English Channel	H. D. Grant	January, 1921
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The Effect of Meteorological Conditions on Aircraft	G. H. Scott & V. C. Richmond	March, 1924
Thunderstorms and Aviation	Dr. G. C. Simpson	January, 1925
The Beneficence of Atmospherics	R. A. Watson Watt	February, 1925

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Further Notes on Aviation in Canada	E. W. Stedman	September, 1924
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Three Years' Flying Experiences	B. C. Hucks	July, 1914
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A Comparison of the Flying Qualities of Single and Twin-Engined Aeroplanes	R. M. Hill	December, 1920
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Experimental Flying from the Pilot's Point of View	R. L. Ragg	November, 1926

Research and Experiment

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The Work of the Advisory Committee for Aeronautics	Sir R. T. Glazebrook	September, 1920
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The Importance of Research in Aeronautics	Council of the R.Aë.S.	February, 1922
Performance Testing of Aircraft	T. M. Barlow	May, 1922
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On Research and Other Matters	S. Heckstall Smith	August, 1922
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Wind Channel Experiments on a Pariah Kite	W. L. Le Page	March, 1923
Theoretical Relationships for Lift and Drag of Aerofoils	H. Glauert	October, 1923
The Vortex Pair Quickly Formed by Some Aerofoils	N. A. V. Piercy	October, 1923
Experimental Aspect of an Assumption of Prandtl's Theory	N. A. V. Piercy	October, 1923
Some Aspects of Aeronautical Progress	Sir F. H. Sykes	December, 1923
The Work of the A.R.C.'s Panel on Scale Effect	W. S. Farren	August, 1924
The Case for the Revival of the Water Channel	N. S. Norway	November, 1924
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Some Aspects of the Comparison of Model and Full-Scale Tests	D. W. Taylor	July, 1925
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Design of Marine Aircraft in Relation to Seaworthiness	D. F. Lucking	November, 1923
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The Journal of the Royal Aeronautical Society is Published Monthly from 7, Albemarle Street, London, W.1, England.

Price 2s. 9d., or £1 12s. 6d. per annum, post free.

Royal Aeronautical Society.

(FOUNDED JANUARY 12th, 1866).

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The Royal Aeronautical Society exists for the furtherance of the Science of Aeronautics. It acts as the professional society or institution of qualified aeronautical engineers, conferring a recognised technical status on those qualified. The Society also organises discussions and publishes papers on subjects of importance in connection with the various branches of aeronautical engineering; encourages and assists technical students who desire to adopt the aeronautical profession for their careers; and provides an organisation wherein all interested in aeronautics, though not necessarily professionally connected with aviation, may meet together and have opportunities to keep themselves in touch with aeronautical affairs.

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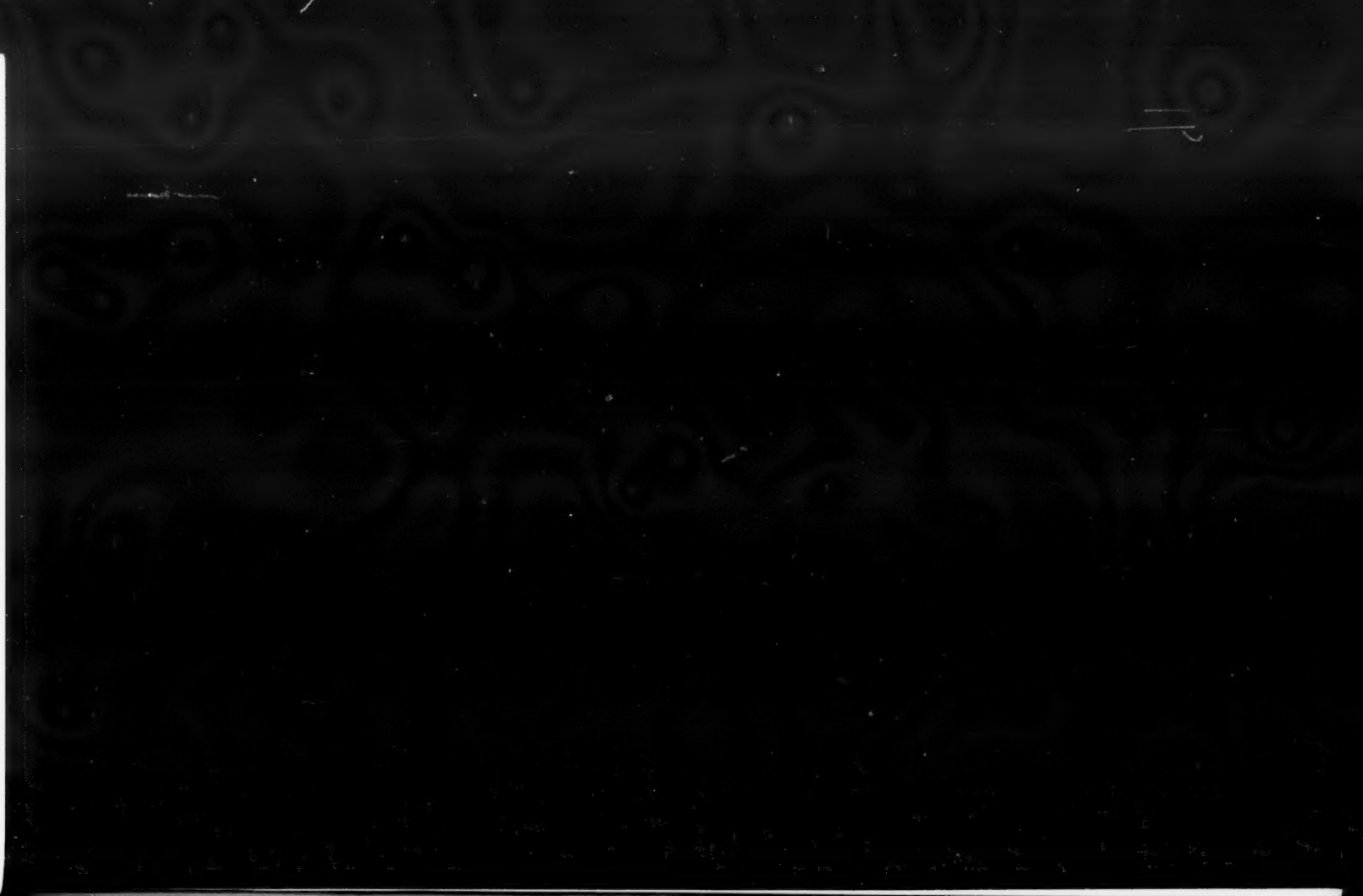
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